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# Essays on growth, financial markets, competition and inequality

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# Abstract

This thesis is broadly involved with growth economics. It starts with a theoretical analysis of the relation between credit markets and economic growth. It considers an exogenous production function model with risky investment projects in which a borrower's (an investor's) risk type is private information. This asymmetry induces lenders to offer loan contracts which separate borrowers as to type. Self-selection can be induced by credit rationing or a screening mechanism which allows lenders to acquire information about a borrower's type. Screening is assumed to be imperfect in the sense that lenders can draw an imperfect inference if borrowers declare themselves as low-risk. The joint determination of the equilibrium loan contract and the economy's growth path and the steady-state capital stock is then explained. The next chapter investigates the extent at which financial development or trade openness of a country influences competition using data for 50 sectors for 8 Eurozone member states and the U.S. over 1981-2004. Financial depth may be associated with greater ease of entry and thus increased competition. Moreover, the effect might be greater in sectors where firms are relatively more dependent on external finance. The relation between trade openness and competition is then investigated. In response to greater foreign competition and increased imports, the market share for domestic producers falls and markups should decline. This relation might be stronger for those industries for which the relative volume of international trade is greater. The fourth chapter is an empirical analysis of the relationship between inequality and growth following on from the AER paper by De La Croix and Doepke. They suggest a mechanism whereby inequality has large effects on growth via the effect on differential fertility of rich and poor and provide empirical support for this thesis. This chapter goes back to the original data and also extends the econometric techniques used to analyze the relationship. Moreover, it suggests a more comprehensive measure of differential fertility and human capital inequality and finds that the relationship between differential fertility and growth is very fragile. It also raises concerns about the use of the squared value of a RHS variable as instrument. This point is addressed in the last chapter which investigates the properties of such instrument and the effect on the

size of the bias of the Instrumental Variables's estimator.

Dedicated to my mom Anna and the memory of my dad Gerasimos

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# Author's Declaration

I declare that the work in this dissertation was carried out in accordance with the Regulations of the University of Bristol. The work is original, except where indicated by special reference in the text, and no part of the dissertation has been submitted for any other academic award. Any views expressed in the dissertation are those of the author.

Signed: Date:

# Contents

# Chapter 1

# Introduction

This thesis is broadly involved with growth economics. It consists of four chapters which discuss distinct though interconnected questions and a concluding part. Credit markets and asymmetric information, competition, financial development and trade openness, income inequality and differential fertility and instrumental variables are some of the concepts which would be also mentioned. In what follows a brief introduction is given to the questions each chapter addresses and this thesis endeavours to assist the advancement of our understanding.

The second chapter investigates the relation between financial markets and economic growth. Although academic research has long acknowledged the link between the two, economists disagree about the exact role of the financial sector in economic growth. The theoretical research has developed around two directions: the potential transmitting mechanisms through which financial development may influence growth, and financial development as a natural outcome of growth itself. Nobel Laureate Merton Miller (1998, p. 14) argues that "[the idea] that financial markets contribute to economic growth is a proposition too obvious for serious discussion". Financial development affects growth by increasing the productivity of investments (as in Greenwood and Jovanovic (1990)) or by increasing the fraction of savings channeled to investment (as in Bencivenga and Smith (1991). However, Greenwood and Jovanovic (1990) and Saint-Paul (1992) argue that financial development is a natural outcome of growth and thus finance responds to changing demands from the "real sector". The empirical research supports the theoretical reasoning. Levine (2005) gives an excellent theoretical and empirical survey.

Advancing our understanding of the role of finance in economic growth will have policy implications as it will influence the priorities that policy makers and advisors set to policies related to reforming the financial sector. Moreover, it will shape interdisciplinary policy-oriented research.

An important feature of financial markets is the possible informational asymmetries between lenders and borrowers. Azariadis and Smith (1993), Tsiddon (1992) and Bencivenga and Smith (1993) show that informational problems cause frictions in financial markets which affect the accumulation of capital and thus economic growth. Lenders need to evaluate potential investment possibilities in the face of asymmetric information (adverse selection) and thus try to separate borrowers as to risk type by means of the borrower's contract choice. In Bencivenga and Smith (1993), this separation is achieved by credit rationing. Bose and Cothren (1996, 1997) build on Bencivenga and Smith (1993) and suggest that self-selection can be induced by credit rationing or a screening mechanism which allows lenders to acquire information about a borrower's type at an exogenous real resource cost.

However, research has treated screening in a simple way. The screening technology is assumed to be perfect in the sense that lenders can identify the type of a screened borrower with certainty. In reality, modern screening techniques are far from perfect. Even more with the current credit crunch which shares characteristics of past financial crises being an obvious proof of that idea. Rationing, on one hand, has been rendered an appealing strategy for most banks as sophisticated securitization processes have been failing and the Basel Rules on capital adequacy are arguably part of the problem, not of the solution. On the other hand, and what is of higher relevance to the motivation of this paper, the credit crunch has showed that although screening techniques have greatly changed since the times of Captain Mainwaring- the banker who knows everyone in his local community- there is still scope and need for great improvement of modern computerised techniques such as credit scoring.

The second chapter of this thesis builds heavily on the afore-mentioned benchmark models of Bencivenga and Smith (1993) and Bose and Cothren (1996, 1997). It addresses the problem of informational imperfections in the credit market and investigates its effects on the capital accumulation process in a neoclassical growth model by making more realistic assumptions about the screening processes. More specifically, screening is assumed to be imperfect. Lenders can identify the true type of the borrowers who declare themselves as high-risk with certainty but can draw an imperfect inference if borrowers declare themselves as low-risk. The accuracy of the inference depends on the quality of the screening technology used.

By examining the case of compulsory screening for the borrowers who declare themselves as low-risk types the main finding of BC, that of the mutual dependency between the equilibrium contract and the equilibrium dynamic path, is verified. However, the assumption of imperfect screening technology although it leads to the same rationing contract with the case where screening is perfect, leads to differences for the screening contract. More specifically, the screening contract is not the same with BC nor unique anymore. Two screening contracts emerge from the maximizing behavior of lenders and borrowers which differ in the probability of rationing some of the borrowers (zero or positive). The ultimate driving force behind the two screening contracts which our model predicts are the cost and/or the quality of screening. Thus, the importance of the assumption about the imperfections in the screening technology is immediately apparent since lower quality of screening might entail rationing some low risk borrowers and thus preventing them from running their investment project. This finding contrasts the predictions of BC who find that under the screening regime all low-risk borrowers get a loan with certainty. Moreover, the model predicts that in undeveloped economies screening is not relevant and the only possible way of separating borrowers is rationing. It is only in developed economies that both means of separating borrowers are feasible and a developed economy grows along the highest dynamic path when the screening technology is used to separate borrowers and none of them is rationed. Contrary to the findings of BC, the screening regime does not always dominate the rationing regime. It follows, that screening is not a panacea for developed countries in the sense of leading to the highest dynamic path and steady state capital stock. Finally, some policy implications are discussed regarding the impact of a change of the screening cost or the quality of screening on the growth path and steady state of capital of an economy in general cases or cases complimentary to the literatures of threshold externalities.

The third chapter engages in the relationship between the competition in different industries across countries, financial development and trade openness. It is an empirical investigation for 50 sectors for 8 Eurozone member states and U.S. over 1981-2004. The degree of competition in a sector is measured by a markup ratio. A markup ratio bigger than one implies that prices exceed marginal costs and are, thus, evidence of market power in a sector. Various macroeconomic variables have been suggested to influence the degree of competition in different industries across countries. Barriers to entry and product differentiation are examples of industry specific determinants of competition whereas openness to trade and financial development are some of the potential country specific factors.

The relation of markups to macroeconomic variables is interesting from the standpoint of competition regulators. Policy-makers need to know whether certain policies are conducive to competition and analysts of trade policy and the financial sector need to understand their effects on competition.

This chapter is part of the research effort attempting to bring the various theoretical predictions to the data. The analysis is based on the Solow residual, a growth accounting methodology which measures the growth rate of productivity. Financial development or trade openness variables are then introduced in an attempt to identify the extent at which they influence competition. More specifically, the relation between financial depth or the degree of banking liberalization and industry competition is investigated. Financial depth may be associated with greater ease of entry and thus increased competition. The chapter also looks on the case of financial depth having a greater effect on competition in sectors where firms are relatively more dependent on external finance, drawing on the central idea of Rajan and Zingales (1998). The relation between trade openness and competition is then investigated. In response to greater foreign competition and increased imports, the market share for domestic producers falls and markups should decline. This relation might be stronger for those industries for which the relative volume of international trade is greater.

The robustness of the findings is examined via the use of different specifications such as cross section estimations, a "two-stage" approach and the simultaneous inclusion of the two macroeconomic variables of interest. Furthermore, different measures of financial development or external dependence and a shorter time period are used.

The findings suggest that financial development has pro-competitive effects. Furthermore, there is strong evidence that increased trade openness is linked with higher competition and thus lower markups. This relation appears to be more robust for industries with a higher degree of tradedness.

The fourth chapter is involved with economic growth and inequality. Growth's enhancement, usually measured through the change in GDP per capita, seems to have been an easy target for modern world. Inequality, on the other hand, is still a distressing, almost embarrassing, fact of the so-called advanced world. According to Milanovic (2002) and Milanovic and Yitzhaki (2002), the group of the most developed countries has the lowest Gini coefficient and high inequality seems to be a characteristic of less developed countries.[1] The income of the developed countries accounts for 58 percent of world income and their population accounts for 16 percent of world's population, the analogue numbers for the "Third World" are 29 percent and 76 percent respectively.

Kuznets (1955) first suggested a link running from output to income distribution with an inverted U-shaped relation. However, later studies have consistently refuted the soundness of the Kuznets hypothesis and have generated skepticism about causal links running from economic growth to inequality.[2] The evidence about the empirical link is controversial. The significance of the estimated coefficients is not always

[1] Inequality is calculated from the world distribution for individuals based entirely on household survey data from several countries, and adjusted for differences in purchasing power parity between the countries.

[2] See, among others, Benabou (1996), Birdsall and Londono (1997), Ravallion and Chen (1997).

convincing and the results are often sensitive to changes in specification and other robustness tests. Benabou (1996) surveys 23 papers on the relationship between growth and inequality. He finds that in ten of these papers there is a consistent significant negative relationship. The other thirteen papers find effectively no correlation.

The empirical inconclusiveness is not surprising since academic research has suggested a variety of ways in which growth and inequality could be linked. Numerous studies try to identify which direction the causality runs. The several suggested mechanisms could be classified in five categories: capital market imperfections channels, political economy, sociopolitical unrest and conflict, saving rates and human capital. Differential fertility has been recently added to suggested mechanisms and Chapter 4 engages in its relativity.

More specifically, Chapter 4 is an empirical analysis of the relationship between inequality and growth following on from the AER paper by De La Croix and Doepke (DLCD). The key point behind the paper of DLCD is that inequality has large effects via the effect on differential fertility of rich and poor and provide empirical support for this thesis. They build on the human capital theory of Becker and Barro (1998) and note that there are two possible channels linking inequality and growth via human capital. First, if there are diminishing returns to human capital at the individual level, then greater human capital inequality will lead to lower growth (holding average education levels constant). This can be seen by considering the effect of a mean-preserving spread on human capital - the loss to the poor (whose marginal product is high) will exceed the gain to the rich (whose marginal product is low). The second channel is differential fertility. People with lower human capital will not only choose less education for their children but also choose a higher number of children. Thus, more weight is put on families who provide little education, which reduces future human capital. In their empirical result, DLCD use a panel data set containing 68 countries over the years 1960-1992 and find that when differential fertility is included in growth regressions, it not only is a better explanatory than inequality, but that inequality ceases to matter at all. This would have two consequences. First, regarding human capital, inequality is related to growth only through the second channel proposed above: diminishing returns are not important. Secondly, there would appear to be no residual explanatory power of inequality via mechanisms (such as political economy) listed earlier.

This chapter focuses on the influence of differential fertility, and contests De La Croix and Doepke's empirical conclusions on two counts. First, some problems with their data is discussed. There are particular problems with the measure of differential fertility which they use, since is frequently based on very small proportions of different countries' populations and is thus likely to contain significant measurement error. The significance of the fertility differential in their results is not robust to different measures of differential fertility or to other important corrections in the data they use. Finally, the econometric techniques used to analyze the relationship are being extended, in particular looking at the reliability of the instrumental variables and panel data techniques. Second, an appropriate measure of human capital inequality, which is the relevant source of inequality according to the theoretical model of DLCD is suggested. A robustness check follows which uses various estimation methods and more general specifications.

One of the points raised in Chapter 4 is the reliability of the instrumental variables used. More specifically, concerns were voiced about the use of the squared value of some of the endogenous RHS variables as instruments. Such a specification might capture any possible non-linear effects between the RHS variables and the independent variable and thus improve the fit of the regression. However, the properties of such instruments as well as the implications for the Instrumental Variables (IV) estimator have not been investigated. The fifth chapter of the thesis investigates whether the squared value of an endogenous RHS variable is a weak instrument and whether the IV estimator is biased in large or small samples. Moreover, it suggests two measures of testing the size of the bias of the IV estimator specific to the case when an endogenous variable is instrumented by its squared value.

Chapter six outlines the conclusions reached by the thesis and discusses interesting extension of the work presented.

# Chapter 2

# Laughing all the way to the bank: Imperfect screening, rationing and growth

## 2.1 Introduction

Academic research has long acknowledged the link between financial markets and economic growth. The theoretical research has developed around two directions: financial development as a natural outcome of growth itself (Greenwood and Jovanovic (1990) and Saint-Paul (1992)) and the potential transmitting mechanisms through which financial development may influence growth. More specificaly, financial systems affect growth by producing information and thus improving resource allocation (Greenwood and Jovanovic (1990)), by monitoring investments and exerting corporate governance after providing finance (Morck, Wolfenzon and Yeung (2005)), by trading, hedging and pooling the risk or by pooling savings (Acemoglu and Zilibotti (1997)) and by easing the exchange of goods and services.

The empirical research supports the theoretical reasoning. King and Levine (1993a, 1993b) give cross-country evidence of the importance of a financial system in determining the rate of economic growth. Jung (1986) and Demetriades and Hussein (1996) are initial time-series studies which show that the direction of causality frequently runs both ways, especially for developing countries. However, later time-series studies document that the dominant direction of causality runs from financial development to economic growth (see, among others, Neusser and Kugler (1998), Rousseau and Wachtel (1998) and Arestis, Demetriades and Luintel (2001)). This hypothesis is also supported when additional econometric sophistication is used (Christopoulos and Tsionas (2004)). Panel data techniques draw a similar picture (Levine, Loayza and Beck (2000), Beck, Levine and Loayza (2000)). Finally, microeconomic-based evidence is consistent with the view that financial development ease external financing constraints which firms face (Rajan and Zingales (1998), Demirguc-Kunt and Maksimovic (1998)). [1]

However, the above research disregards an important feature of the financial market, the possible informational asymmetries between lenders and borrowers. Azariadis and Smith (1993), Tsiddon (1992) and Bencivenga and Smith (1993) show that informational problems cause frictions in financial markets which affect the accumulation of capital and thus economic growth. This asymmetry induces lenders to offer loan contracts that separate borrowers as to type (high-risk versus low-risk) by means of the borrower's contract choice. To that purpose, an environment that induces self-selection is needed. In Bencivenga and Smith (1993), this separation is achieved by credit rationing. Bose and Cothren (1996, 1997) build on Bencivenga and Smith (1993) and suggest that self-selection can be induced by credit rationing or a screening mechanism which allows lenders to acquire information about a borrower's type at an exogenous real resource cost. However, screening is modeled in a simple way. The screening technology is perfect in the sense that lenders can identify the type of a screened borrower with certainty.

In reality, the mere nature of asymmetric information not only imposes an ex ante (to the screening process) asymmetry but it even allows for the possibility of

[1] For a detailed survey of the theoretical and empirical literature on the relationship between financial development and growth see Levine (2005).

ex post asymmetry. Even more with the current credit crunch, the need to vastly reconsider rationing and screening tactics is vital. Rationing, on one hand, has been rendered an appealing strategy for most banks as sophisticated securitization processes have been failing and the Basel Rules on capital adequacy are arguably part of the problem, not of the solution. On the other hand, and what is of higher relevance to the motivation of this paper, the credit crunch has showed that although screening techniques have greatly changed since the times of Captain Mainwaring- the banker who knows everyone in his local community- modern computerised techniques such as credit scoring are still far from perfect.

This paper builds heavily on the afore-mentioned benchmark models of Bencivenga and Smith (1993) and Bose and Cothren (1996, 1997, henceforth BC). It tries to address the problem of informational imperfections in the credit market and investigate its effects on the capital accumulation process by making more realistic assumptions about the screening processes. More specifically, screening is assumed to be imperfect. Lenders can identify the true type of the borrowers who declare themselves as high-risk with certainty but can draw an imperfect inference if borrowers declare themselves as low-risk. The accuracy of the inference depends on the quality of the screening technology used. We examine the case when screening is compulsory for the borrowers who declare themselves as low-risk types.

The predictions of BC can be seen as a special case of our model (perfect accuracy of lenders' inference about the risk type of borrowers or maximum quality of screening). They consider a neoclassical growth model and show that when screening is perfect, the contract's form in equilibrium (rationing or screening) depends on the level of the capital accumulation in the economy and vice versa. In other words, there is a mutual dependency and thus the equilibrium contract and the equilibrium dynamic path are jointly determined. They find that for low levels of capital, lenders use rationing but as capital accumulates lenders may start using the screening technology to separate borrowers. The dynamic path of the economy whose lenders use screening is higher than the dynamic path of an economy whose lenders use rationing and this corresponds to a higher steady state capital stock. In that way, they reinforce the findings of the literature on the connection between economic and financial development.

Our model predicts that assuming the screening technology is imperfect does not affect the rationing contract but the screening contract is not the same nor unique anymore. Two screening contracts emerge from the maximizing behavior of lenders and borrowers which differ in the probability of rationing some of the borrowers (zero or positive). The ultimate driving force behind the two screening contracts which our model predicts are the cost and/or the quality of screening. Thus, the importance of the assumption about the imperfections in the screening technology is immediately apparent since lower quality of screening might entail rationing some low risk borrowers and thus preventing them from running their investment project. This finding contrasts the predictions of BC who find that under the screening regime all low-risk borrowers get a loan with certainty. Moreover, our predictions vary with the level of development of the economy. In undeveloped economies screening is not relevant and the only possible way of separating borrowers is rationing. It is only in developed economies that both means of separating borrowers are feasible. We show that a developed economy grows along the highest dynamic path when the screening technology is used to separate borrowers and none of them is rationed. Contrary to the findings of BC, we show that the screening regime does not always dominate the rationing regime. It follows, that screening is not a panacea for developed countries in the sense of leading to the highest dynamic path and steady state capital stock. The mutual dependency between the equilibrium contract and the equilibrium dynamic path is a corollary of our model, similarly to BC. Finally, we investigate the impact of a change of the screening cost or the quality of screening on the growth path and steady state of capital of an economy and verify previous findings that there are cases for which the cost of screening must fall below a threshold level before it can affect the economy's growth path and steady state level of capital. We find that the same holds for the quality of screening.

The rest of the paper proceeds as follows. In section 2 we give a description of the economy. In section 3 we derive the contracts which would be offered under perfect information in a framework otherwise similar to BC's. Then, we reproduce the asymmetric information model of Bencivenga and Smith (1993) and BC and show the rationing and screening contracts when screening is perfect. In section 4 we introduce imperfect screening and derive the terms of the equilibrium loan contracts. Moreover, we show that lenders can use rationing or screening in order to separate borrowers only in developed economies whereas rationing will be always be used in undeveloped economies. Since monitoring is assumed to be a costly activity which involves using productive resources, in section 5 we check how this might affect both the growth path of a developed economy and the steady state under each contracting regime. In section 6 we derive the equilibrium regimes for a developed economy and some interesting policy implications are discussed in section 7. Section 8 concludes.

## 2.2 Description of the economy

### 2.2.1 The credit market

A discrete time economy is considered and time is indexed by $t = 1, 2, ..., \infty$. There is an infinite sequence of two-period-lived agents of overlapping generations plus a set of initial old agents. The number of agents of each period is normalized to one, of which half are lenders and half are borrowers or entrepreneurs. All young agents are endowed with one unit of labour. The initial old generation of entrepreneurs in the economy is endowed with capital. Agents consume only in the second period.

The credit market works as follows. Each lender announces loan contracts at time $t$, taking the contracts' announcement by the rest of the lenders as given. Then, each lender is approached by a single borrower if his announced contracts are not dominated by those of another lender.

Lenders at the first period of their lives (young lenders) offer their labour to the firms of the entrepreneurs (i.e. the borrowers of the previous generation or old borrowers) and obtain $w_t$ units of time $t$ output i.e. the real wage. Lenders can use the proceeds by converting them to $t+1$ capital according to their "home production" technology. The home technology converts one unit of the $w_t$ units of time $t$ output to $Q\varepsilon$ units of time $t+1$ capital, where $Q$ is a scalar and $0 < \varepsilon < 1$. Alternatively, lenders can lend their proceeds to an entrepreneur through the loan market. In the second period lenders rent their $t+1$ capital at the rate $\rho_{t+1}$ for time $t+1$ output and consume. Since the safe return gives the lender $Q\varepsilon\rho_{t+1}w_t$ units of time $t+1$ output, the opportunity cost rate of loaning the funds is $Q\varepsilon\rho_{t+1}$. We assume that there is perfect competition and thus lenders earn zero economic profit on each contract and they are risk neutral.

Borrowers are endowed with an investment project and they belong to two types, $H$ and $L$. The type $L$ borrower is a low-risk and high-return borrower and the type $H$ borrower is a high-risk and low-return borrower. A fraction $\lambda \in [0, 1]$ of the borrowers is of type $H$. The first period, borrowers can choose between home production and operation of their investment projects. The materialization of the investment project requires the borrower's own labour and an amount of time $t$ output. Since young borrowers are not endowed with time $t$ output they need to apply for a loan. If a loan of $w_t$ units of time $t$ output is obtained, then with probability $p_i$ the investment project converts one unit of the $w_t$ units of time $t$ output to $Q$ units of $t+1$ capital and with probability $(1-p_i)$ the investment project yields zero, where $p_i$, $i = L, H$ is the "entrepreneurial ability" of the borrower or the probability of success of the investment project. The values $p_i$ satisfy $1 \geq p_L > p_H \geq 0$. This capital can be invested in the second period to give the borrower a return of time $t+1$ output. However, if a young borrower is unable to obtain a loan he uses his own labour according to his "home production" technology to produce $\beta_i$ units of time $t+1$ output. We assume that $\beta_L > \beta_H \geq 0$. This can be viewed as asserting that type $L$ borrowers who have higher probability of success $p_L$ in their investment projects, also have higher quality of labour or access to a higher quality of home production technology which results in a higher home production output $\beta_L$.

Note that the borrowers who are denied a loan, cannot "sell" their labour like lenders but are precluded from doing so by the timing of events. This assumption is imposed in order to ensure that the different types of borrowers have different opportunity costs if they are denied credit.[2] In this model, this is reflected by the difference in the home production output between the two types. In effect, the inequality $\beta_L/p_L > \beta_H/p_H$ implies that the indifference curves of the two different types of borrowers have different slopes and thus a standard "single-crossing" property on borrowers' indifference curves is imposed.

Figure 1 summarizes the mechanism of the credit market.

| | **Period 1: Production** | | |
|---|---|---|---|
| **Lenders** | Offer labour for $w_t$ units of $y_t$ | Lend $w_t$ units of $y_t$ | receive $w_t(1+R_t)$ units of $k_{t+1}$ with prob. $p_i$ |
| | | | receive 0 with prob $(1-p_i)$ |
| | | Home production | produce $Q\varepsilon w_t$ units of $k_{t+1}$ |
| **Borrowers** | Use labour on own project or home production | Borrow $w_t$ units of $y_t$ | produce $Qw_t$ units of $k_{t+1}$ with prob. $p_i$ |
| | | | produce 0 with prob. $(1-p_i)$ |
| | | Home production | produce $\beta_i$ units of $y_{t+1}$ |

Figure 1

### 2.2.2 The output market

In period $t+1$, the output producing firms become active. The operators of the firms are the borrowers of period $t$ (all the borrowers, not only the successful ones). The entrepreneurs rent capital in positive or negative amount (from the current generation) and hire labour (from the young generation) at the competitive rental rates $\rho_{t+1}$ and $w_{t+1}$ respectively. The production function exhibits constant returns

[2]It will become obvious that such an assumption allows us to induce self-selection in the case of credit rationing.

to scale. A firm employing $k_t$ units of capital and $L_t$ units of labour produces $y_t$ units of output according to the exogenous production function:

$$y_t = k_t^{\theta} L_t^{1-\theta}$$

The above production function needs some explanation. There is complete factor mobility and hence in equilibrium all firms employ an equal amount of labour. Since all borrowers become firm operators the number of firms per capita is 0.5. The per capita supply of labour is restricted to the number of those agents called lenders i.e. 0.5 (remember that borrowers who are denied credit are excluded from selling their labour by the timing of events). Hence, at each time period the employees per firm is $labour/firm \equiv L_t = 1$.[3]

### 2.2.3 Information structure

The main difference between our model and a standard overlapping generations model is the existence of informational asymmetries between capital-producing firms and lenders. Each lender offers a set of loan contracts for which the borrowers have complete knowledge but the type of the borrower is private information. The lender separates the borrowers either by rationing or by screening the quality of the project at a resource cost.

## 2.3 Benchmark equilibrium contracts

Before analyzing the equilibrium contracts under imperfect screening we need to understand how the benchmark models works. We start by deriving the equilibrium

[3]Obviously, the aggregate output is $Y_t = \sum_{i=0}^{i=0.5} y_{it}$.

contracts under perfect information. Then we show how the contract terms change once we relax that assumption. More specifically we explain how credit rationing and perfect screening can provide a solution to the problem of asymmetric information by reproducing the model of BC.

### 2.3.1 Perfect information

When there is perfect information in the credit market, competition leads lenders to offer the best break-even contract for each type of borrowers. The contracts terms are: $R_{it}$, the interest rate offered to type $i$ borrower at time $t$, $q_{it}$, the quantity of loan offered to type $i$ borrower at time $t$ and $\pi_{it}$, the probability of getting a loan for the type $i$ borrower at time $t$. Lenders offer the contracts $C_H = (R_{Ht}, q_{Ht}, \pi_{Ht})$ and $C_L = (R_{Lt}, q_{Lt}, \pi_{Lt})$ that maximize the expected payoff of $H$ and $L$ type borrowers respectively, subject to the restrictions of the model.

We start the analysis by defining the expected payoffs of the borrowers. With probability $\pi_i$ the borrower gets a loan $q_t$ and thus operates his investment project. With probability $p_i$ the project succeeds and yields $Qq_t$ units of time $t+1$ capital. This capital can be invested in the second period at the rate $\rho_{t+1}$ and used to produce time $t+1$ output. The borrower pays back his lender at the interest rate $R_{it}$. With probability $(1-p_i)$ the project fails and yields zero in which case the borrower doesn't repay his lender. Finally, with probability $(1-\pi_{it})$ the borrower does not get a loan and thus uses his home production technology. So, the expected payoff for the borrowers is:

$$EP_i(C_i) = \pi_{it} p_i \left(Q\rho_{t+1} - R_{it}\right) q_{it} + (1-\pi_{it})\beta_i \tag{2.1}$$

The following restrictions need to be satisfied by the equilibrium contracts:

$$\pi_{it} q_{it} \left(p_i R_i - Q\varepsilon\rho_{t+1}\right) = 0 \tag{2.2}$$

$$q_t \leq w_t \tag{2.3}$$

$$0 \leq \pi_{it} \leq 1 \tag{2.4}$$

$$\pi_{it} p_i \left(Q\rho_{t+1} - R_{it}\right) q_{it} + \left(1 - \pi_{it}\right) \beta_i \geq \beta_i \tag{2.5}$$

Equation (2.2) is the zero profit condition of the lender (obviously, the cost depends on the opportunity cost of the loaned funds). Equation (2.3) is a constraint for the supply of loans and shows that the amount of a loan $q_t$ the borrowers get is restricted by the lenders' wage. Expression (2.4) is a constraint for the probability of getting the loan. Lastly, (2.5) is the participation constraint of the borrowers. Borrowers may have another opportunity available to them which gives some reservation level of utility. The principal (lender) must ensure that the expected payoff for the agent (borrower) is at least this reservation level in order to be willing to participate. The outside option in this case is the home technology output $\beta_i$. We assume that the participation constraint is not binding and we ignore it during the maximization process. We then verify that this assumption holds for the equilibrium contract terms.

Moreover, lenders have a participation consrtraint too. With probability $p_i$ the borrower is successful in his investment project in which case the lender gets a return of $R_i$. With probability $(1 - p_i)$ the investment project fails and the lender gets nothing. Alternatively, the lender does not give a loan and can thus convert his wage into time $t + 1$ capital according to his home production. Intuitively, the lender's expected payoff from a loan is at least as high as the expected payoff from the safe investment. Thus, the participation constraint of the lender is:

$$p_i q_{it} \left(1 + R_i\right) \geq q_{it} Q \varepsilon$$

We solve the zero profit condition (2.2) to get the equilibrium interest rate:

$$R_{it} = \frac{Q\varepsilon\rho_{t+1}}{p_i} \tag{2.6}$$

We find that as long as

$$p_i Q\rho_{t+1}w_t > \beta_i + Q\varepsilon\rho_{t+1}w_t \tag{2.7}$$

holds, the expected payoff for borrowers is strictly increasing in both control variables and thus maximized by the corner solution

$$q_{it} = w_t$$

and

$$\pi_{it} = 1$$

**Proof.** Given that lenders earn zero profit on the loans, both high and low risks borrowers receive their first best contract. So, the expected payoff of the borrowers is increasing in the control variables $\pi_{it}$ and $q_{it}$ when:

$$\frac{\partial EP_i\left(C_i\right)}{\partial \pi_{it}} = p_i\left(Q\rho_{t+1} - R_{it}\right)q_{it} - \beta_i > 0 \tag{2.8}$$

and

$$\frac{\partial EPi\left(C_i\right)}{\partial q_{it}} = \pi_{it}p_i\left(Q\rho_{t+1} - R_{it}\right) > 0 \tag{2.9}$$

Obviously, if (2.8) holds then (2.9) is automatically satisfied. However, using the zero profit interest rate $R_{it}$ and the feasibility constraint (2.3), (2.8) reduces down to:

$$\left(p_i - \varepsilon\right)Q\rho_{t+1}w_t > \beta_i \tag{2.10}$$

So, as long as (2.10) holds, the expected payoff for borrowers is strictly increasing at both control variables i.e. the maximization has a corner solution.

Notice that the participation constraint is indeed non-binding. If we substitute

$\pi_{it} = 1$ in (2.5) we obtain:

$$p_i \left(Q\rho_{t+1} - R_{it}\right) q_{it} \geq \beta_i$$

which holds with strong inequality due to (2.8). ■

Hence, the equilibrium contracts under full information are

$$C_H = (R_{Ht}, q_{Ht}, \pi_{Ht}) = \left(\frac{Q\varepsilon\rho_{t+1}}{p_H}, w_t, 1\right)$$

and

$$C_L = (R_{Lt}, q_{Lt}, \pi_{Lt}) = \left(\frac{Q\varepsilon\rho_{t+1}}{p_L}, w_t, 1\right)$$

Obviously, the actual rate of return from the investment project should be positive in order for borrowers to be willing to operate their investment projects i.e. $p_i \left(Q\rho_{t+1} - R_{it}\right) > 0$. Since there are positive expected profits for the borrowers on each unit borrowed it is clear now that the above mentioned assumption of a borrower being able to approach just a single lender aims at bounding the expected profits for the borrowers. As Bencivenga and Smith (1993) note it is not essential that there is one-to-one match, rather that each borrower can contact a finite number of lenders.

Moreover, we make the common assumption that if a borrower is indifferent between the two types of contracts, he chooses the contract designed for his type. Such an assumption is imposed to guarantee the existence of a closed feasible set.

For future reference it should be noted that since $\beta_i$ is a non-negative number, (2.10) implies that:

$$p_i > \varepsilon \tag{2.11}$$

This can be interpreted as $\varepsilon$ being sufficiently smaller than $p_i$ to ensure loans between borrowers and lenders are mutually desirable.

### 2.3.2 Imperfect information

This subsection reproduces the model of BC to show how rationing and screening emerge as a solution to the problem of asymmetric information.

#### Rationing

Credit rationing describes the situation when a lender limits the supply of loans at a level lower than the demand of prospective borrowers, although some borrowers would accept even higher interest payments. Stiglitz and Weiss (1981) argue that banks may prefer to reject some borrowers because of adverse selection and incentive effects. A higher interest rate attracts riskier borrowers or creates an incentive for borrowers to undertake projects with higher returns and thus higher risk. So, if the number of risky borrowers in the pool of aspiring borrowers increases then the profitability of the bank will decrease.

The timing of contracting assumed is given by figure 2.

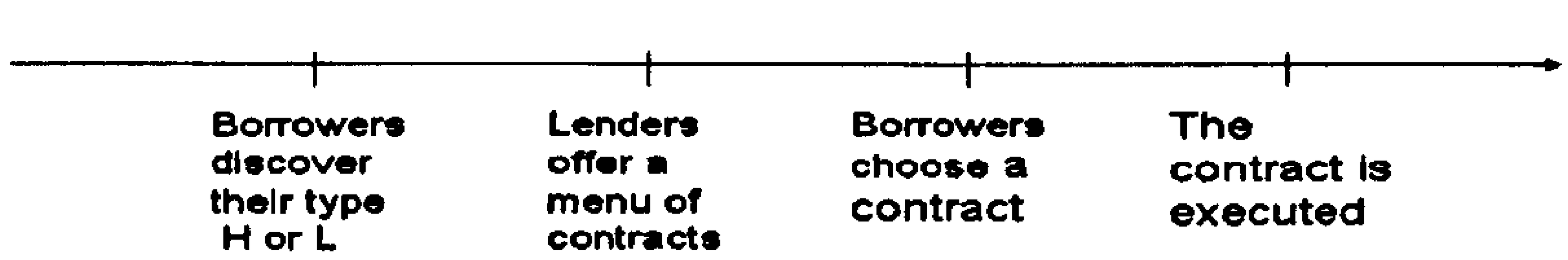


Figure 2: Timing of Contracting Under Rationing

The separating equilibrium can be derived as follows. Since competition leads lenders to offer the best break-even contract for each type, both types of borrowers will be offered the maximal contracts for them i.e. the best interest rate, quantity of credit and rationing probability among the set of contracts that satisfy the constraints of the model. We show that an $H$ type borrower gets his first-best contract, since a low-risk borrower has no incentive to be considered as a high-risk one, but an $L$ type borrower gets the second-best contract. In other words, $C_L$ is now affected by considerations of self-selection but $C_H$ doesn't need to deviate. The lender will distort the low-risk borrower's contract $C_L$ in such a way that the high-risk borrower is at least as well off accepting $C_H$. In this section, the distortion will be achieved by rationing a fraction of low-risk borrowers. It is thus possible to derive the following Lemma.

**Lemma 1** *The first-best contract for type L is affected by considerations of self-selection but not the first-best contract for type H.*

**Proof.** Let $C_H$ and $C_L$ denote the first-best contracts for type $H$ and $L$ respectively, with terms $C_H = \left(\frac{Q\varepsilon\rho_{t+1}}{p_H}, w_t, 1\right)$ and $C_L = \left(\frac{Q\varepsilon\rho_{t+1}}{p_L}, w_t, 1\right)$. Hence, $EP_H(C_L) > EP_H(C_H)$ since $p_H\left(Q\rho_{t+1} - \frac{Q\varepsilon\rho_{t+1}}{p_L}\right)w_t > p_H\left(Q\rho_{t+1} - \frac{Q\varepsilon\rho_{t+1}}{p_H}\right)w_t$ or $p_L > p_H$. However, $EP_L(C_H) < EP_L(C_L)$ since $p_H\left(Q\rho_{t+1} - \frac{Q\varepsilon\rho_{t+1}}{p_H}\right)w_t < p_L\left(Q\rho_{t+1} - \frac{Q\varepsilon\rho_{t+1}}{p_L}\right)w_t$ or $p_H < p_L$. In other words $C_L$ is affected by considerations of self-selection but not $C_H$. ■

If a young borrower gets a loan, he combines it with his labour endowment and materializes his investment project from which he produces time $t+1$ capital. However, if the borrower is rationed, he uses his labour endowment according to his home production technology which results in old age consumption $\beta_i$ units of time $t+1$ output. The expected payoffs of the borrowers are defined as follows: With probability $\pi_i$ the borrower gets a loan $q_t$ and thus operates his investment project. With probability $p_i$ the project succeeds and yields $Qq_t$ units of time $t+1$ capital. This capital can be invested in the second period at the rate $\rho_{t+1}$ and produces time $t+1$ output. The borrower pays back his lender at the interest rate $R_{it}$. With probability $(1-p_i)$ the project fails and yields zero in which case the borrower doesn't repay his lender. Finally, with probability $(1-\pi_{it})$ the borrower does not get a loan and thus uses his home production technology. So, the expected payoff for the borrowers is as given in (2.1).

In a situation of asymmetric information there are typically two sorts of constraints involving the borrower. The first is the participation constraint similar to the case of perfect information which we explained above. The participation constraints, for types $L$ and $H$ respectively, are:

$$\pi_{Lt}p_L\left(Q\rho_{t+1} - R_{Lt}\right)q_{Lt} + (1 - \pi_{Lt})\,\beta_L \geq \beta_L \tag{2.12}$$

$$\pi_{Ht}p_H\left(Q\rho_{t+1} - R_{Ht}\right)q_{Ht} \geq 0 \tag{2.13}$$

For the rest of the analysis we make the simplifying assumption that the home technology output for the high-risk borrower is zero i.e. $\beta_H = 0$.

The second kind of constraint is an incentive compatibility constraint and is specific to cases of asymmetric information. An incentive compatibility constraint shows that if a lender wants the borrower to choose the contract designed for his type, he must offer him one which gives him an incentive to do so. In other words, the lender should ensure that an $H$ type borrower would prefer the contract intended for him rather than the $L$ type's contract and vice versa. To that effect, we need to assume that the expected payoff in the case where the borrower reveals his type is greater than the payoff in the case where he conceals it. So, in order to induce types $L$ and $H$ borrowers respectively to self select, the pair of contracts $(C_L, C_H)$ in equilibrium should satisfy the following incentive compatibility constraints:

$$\begin{aligned}&\pi_{Lt}p_L\left(Q\rho_{t+1} - R_{Lt}\right)q_{Lt} + (1 - \pi_{Lt})\,\beta_L \geq \\ &\pi_{Ht}p_L\left(Q\rho_{t+1} - R_{Ht}\right)q_{Ht} + (1 - \pi_{Ht})\,\beta_L\end{aligned} \tag{2.14}$$

$$\pi_{Ht}p_H\left(Q\rho_{t+1} - R_{Ht}\right)q_{Ht} \geq \pi_{Lt}p_H\left(Q\rho_{t+1} - R_{Lt}\right)q_{Lt} \tag{2.15}$$

The left-hand side of (2.14) measures the expected payoff for a low-risk borrower when he truthfully reveals his type and takes the contract $C_L$ whereas the right-hand side measures the expected payoff when he claims to be a high risk and takes the contract $C_H$. Expression (2.15) is similarly interpreted. Thus, under (2.14) and

(2.15), borrowers choose truth-telling which weakly dominates lying. It should be noted that the Revelation Principle has been applied which restricts the contract terms to the pair of optimal choices made by the two types of borrowers and thus has simplified greatly the incentive compatibility constraints.

We proceed by using the common approach where the incentive compatibility constraint of the type whose contract is not affected by considerations of self-selection, is binding.[4] It follows that the incentive compatibility constraint of the $L$ type is not binding. After deriving the equilibrium contracts, we will verify that these assumptions are valid (see Proof 1). Similarly, it is assumed that both participation constraints are not binding and thus are being ignored during the maximization procedure. In Proof 2 we verify that the participation constraints of the two borrowers are indeed not binding for the equilibrium contract terms and hence can be correctly ignored during the maximization (case 1). We also derive the equilibrium contract assuming that the incentive compatibility constraint of the type whose contract is affected by considerations of self-selection is binding and prove that this leads to a contradiction (case 2).

In order to deter type $H$ borrowers from applying for the $C_L$, competition leads the lender to offer contract terms which maximize the $H$ type borrower's expected payoff subject to his own zero profit condition, the incentive compatibility constraint of type $L$ borrowers and the feasibility constraint. However, this problem can be simplified since the incentive compatibility of type $L$ borrowers is not binding. In other words the $L$ type has no incentive to be considered as an $H$ type and so the terms of the contract $C_H$ are not affected by the behavior of the $L$ type borrower. Thus the problem becomes identical to the case of perfect information. So, as long as (2.9) holds, the expected payoff for type $H$ borrowers is strictly increasing in both control variables and thus maximized by the corner solution. The interpretation is that if a borrower denotes himself as type $H$, he is automatically offered the contract

[4] This equilibrium outcome is quite typical in models with adverse selection. It mainly emerges due to the equilibrium interest rate differential since the low-risk borrowers are offered a lower interest rate than the high-risk borrowers. So, the high-risk borrowers have an incentive to mimic the low-risk borrowers but not vice versa (see proof).

$C_H$ which he always accepts.

However, the equilibrium contract $C_L$ is affected by considerations of self-selection since $H$ type borrowers would want to conceal their true type and get the contract designed for the low-risk type. Thus the lender offers the contract $C_L^r = (R_{Lt}, q_{Lt}, \pi_{Lt})$ that maximizes the $L$ type borrower's expected payoff subject to his own zero profit condition, the incentive compatibility constraint of type $H$ borrower and the feasibility constraint, i.e.:

Maximize

$$EP_L(C_L) = \pi_{Lt} p_L \left(Q\rho_{t+1} - R_{Lt}\right) q_{Lt} + (1 - \pi_{Lt})\beta_L$$

subject to

$$\pi_{Lt} q_{Lt} \left(p_L R_L - Q\varepsilon\rho_{t+1}\right) = 0$$

$$q_{Lt} \leq w_t$$

$$0 \leq \pi_{Lt} \leq 1$$

$$\pi_{Ht} p_H \left(Q\rho_{t+1} - R_{Ht}\right) q_{Ht} \geq \pi_{Lt} p_H \left(Q\rho_{t+1} - R_{Lt}\right) q_{Lt}$$

In Proof 1 we show that as long as (2.7) holds, the equilibrium contract terms are

$$C_L^r = (R_{Lt}^r, q_{Lt}^r, \pi_{Lt}^r) = \left(\frac{Q\varepsilon\rho_{t+1}}{p_L}, w_t, \frac{1 - \varepsilon/p_H}{1 - \varepsilon/p_L}\right)$$

Summarizing, this section shows that, under the rationing regime, high risk borrowers receive the same contract as when there are no informational imperfections in the credit market. However, the contract for low risk borrowers is distorted and the distortion is achieved by rationing a fraction of low-risk borrowers. An $L$ type borrower is offered the same amount of credit with a high risk borrower but a lower interest rate and his contract bears a positive probability of rationing in order to deter the high risk borrowers from applying for it.

### Perfect screening

Another way to combat the adverse selection problem that arises due to asymmetric information is through screening. Lenders can investigate potential borrowers, aiming to distinguish between high risk and low risk ones. Screening in practice can take various forms. Old fashioned banking as described by Captain Mainwaring- a bank manager who knew everyone in his local community- has given way to automatic computerised and complicated techniques such as credit scoring. Credit scoring uses a borrower's financial history and current assets and liabilities to implement a statistical analysis of creditworthiness. Lenders, such as banks and credit card companies, use credit scores to determine a potential borrower's ability to repay debt and the contract terms such as the interest rate and the credit limit. A poor credit rating indicates a high risk of defaulting on a loan, and thus leads to high interest rates, or the refusal of a loan by the creditor.

This section reproduces the screening contract of BC. According to their framework, lenders are assumed to investigate the type of a fraction only of the potential borrowers who declare themselves as low-risk. The probability of a borrower being screened when applying for a loan is $(1 - \phi)$. Screening implies a real cost $\gamma$ proportional to the amount lent i.e. if $q^s_{Lt}$ is the amount of the loan then the screening cost is $\gamma q^s_{Lt}$.[5] Screening is assumed to allow the lender to identify the borrower's true type with certainty. The optimal level of screening $(1 - \phi^*)$ is endogenous. The timing of contracting is given by Figure 3.

[5] This proportionality leads to more intuitive results since a non-proportional cost does not allow the derivation of analytical solutions for the dynamic growth paths.

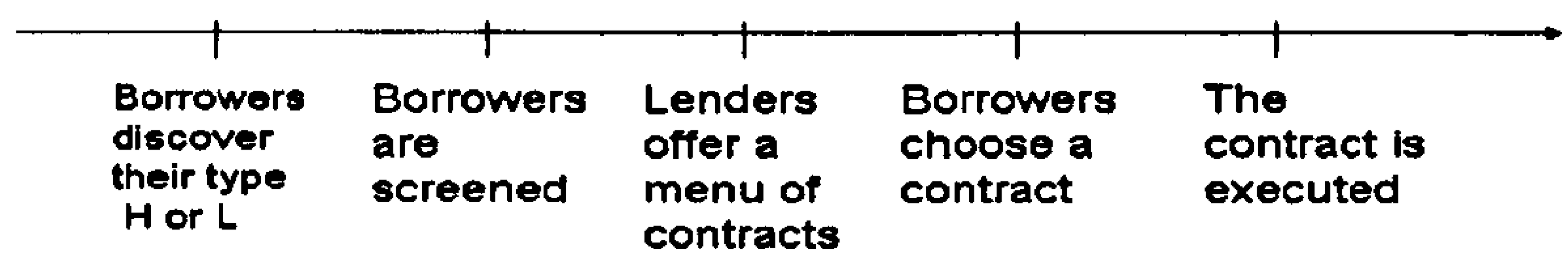


Figure 3. Timing of Contracting Under Perfect Screening

It should be reminded that, in the rationing regime, $H$ type borrowers receive their first-best contract. Low-risk borrowers have no incentive to be considered as high-risk and thus there are no considerations of self-selection. Moreover, given that screening is costly, no further improvement in the expected payoff of the high-risk borrowers is possible by including any element of screening in their contract $C_H$. Thus, in an environment where lenders have the option of screening the borrowers, the contract offered to the $H$ type borrowers will not change. In other words, the borrowers that declare themselves to be type $H$ are not screened and are offered their first-best contract $C_H$.

This is not the case for the low-risk borrowers though. We have already shown that in a rationing regime the low-risk borrowers face a positive probability of being rationed. The amount of credit or the interest rate have to be different than those offered under a rationing regime since now there are resources spent for the screening realization. What we will show is that if screening results in a net gain for the low-risk borrower, then there will exist a separating equilibrium which is described by the same $C_H$ contract for the high-risk borrowers but the contract $C_L$ will be replaced by the contract:

$$C_L^s = [(\phi_t, R_{Lt}^n, q_{Lt}^n, \pi_{Lt}^n) ; ((1-\phi_t), R_{Lt}^s, q_{Lt}^s)]$$

which involves some level of screening. Note that the rationing variable $\pi_{it}$ does not enter into the contract terms for the screening case. The reason is that with screening, the borrowers' true type is revealed and hence, the low risk borrowers are funded with certainty i.e. $\pi_{Lt}^s = 1$. However, lenders can ration some low risk borrowers if they are not screened (we will anyway show that lenders do not find it optimal to mix screening with rationing i.e. $\phi_t > 0, \pi^n_{Lt} = 1$). Finally, if a screened borrower is found to be high-risk, he is denied credit.

Since we assume that lenders earn zero economic profit on each contract, they will select those $R^s_{Lt}, R^n_{Lt}, q^s_{Lt}, q^n_{Lt}, \pi^n_{Lt}, \phi_t$ that maximize the expected utility of the low risk type subject to their own zero profit condition, the incentive compatibility constraint of the high risk type and the feasibility constraint on the amount of the loan (in the states with and without screening). Similarly to before, we assume that the participation constraints for the two types of borrowers and the incentive compatibility constraint of the low risk borrowers are not binding and thus are being ignored. To save on space we only give these constraints in the Appendix where we also verify that there are not binding for the equilibrium contract terms.

So, the problem for an $L$ type borrower is:

Maximize

$$EP_L\left(C^s_L\right) = \phi\left(\pi^n_{Lt} p_L \left(Q\rho_{t+1} - R^n_{Lt}\right) q^n_{Lt} + \left(1 - \pi^n_{Lt}\right)\beta_L\right) + (1-\phi)\, p_L \left(Q\rho_{t+1} - R^s_{Lt}\right) q^s_{Lt}$$

subject to

$$\phi \pi^n_{Lt} p_L q^n_{Lt} R^n_L + (1-\phi)\, p_L q^s_{Lt} R^s_L = \phi \pi^n_{Lt} q^n_{Lt} Q \varepsilon \rho_{t+1} + (1-\phi)\, q^s_{Lt}\,(1+\gamma)\, Q\varepsilon\rho_{t+1}$$

$$\pi_{Ht} p_H \left(Q\rho_{t+1} - R_{Ht}\right) q_{Ht} \geq \phi \pi^n_{Lt} p_H \left(Q\rho_{t+1} - R^n_{Lt}\right) q^n_{Lt}$$

$$q^n_{Lt} \leq w_t$$

$$q^s_{Lt} \leq w_t - q^s_{Lt}\gamma$$

Notice that since the screening cost is defined as a resource cost $\gamma$ proportional to the amount lent, it is not added as an extra cost on the right hand side of the zero profit condition of the lender but is embodied in the amount of the loan. The maximization problem is solved similarly to the way described for the rationing contract and is given in detail in the Appendix (see Proof 3). We find that as long as (2.7) holds, the screening contract is:

$$C_L^s = \left[ \left( \phi_t, R_{Lt}^n, q_{Lt}^n, \pi_{Lt}^n \right); \left( (1-\phi_t), R_{Lt}^s, q_{Lt}^s \right) \right] =$$

$$\left[ \left( 1 - \frac{\varepsilon}{p_H} + \frac{\varepsilon}{p_L}, \frac{Q\varepsilon\rho_{t+1}}{\phi p_L}, w_t, 1 \right); \left( \frac{\varepsilon}{p_H} - \frac{\varepsilon}{p_L}, 0, \frac{w_t}{1+\gamma} \right) \right]$$

The interpretation of the above findings is straightforward. In equilibrium the high risk borrower still gets his first-best contract $C_H$, but the low-risk borrower gets a contract which involves some level of screening. The low-risk borrowers are screened with a positive probability in which case the amount of the loan is less the screening cost. The interest rate in the case of screening is $R_{Lt}^s = 0$ which implies that the burden of interest rate payment is shifted to the non-screening state. As explained in the proof, none of the interest rates appear in the simplified version of the objective function (after substituting the zero profit condition in the objective function) but $R_{Lt}^n$ appears (negatively) on the right hand side of the incentive compatibility constraint of the high-risk borrower. So, the lender should set $R_L^n$ as high as possible in order to deter an $H$ type borrower from applying for a $C_L$ contract. It is obvious from the zero-profit condition that this implies that $R_L^s$ should be set as low as possible. Moreover, the interest rate in the non-screening state had to be higher under the rationing in order to make up for expected losses. Finally, we show that the incentive compatibility constraint is still binding for the $H$ type borrower.

Note that the screening contract implies the funding of a greater number of low-risk projects relative to the rationing contract since $\pi_L^s(1-\phi) + \pi_L^n \phi > \pi_L^r$ or $1 > \frac{1-\varepsilon/p_H}{1-\varepsilon/p_L}$. Moreover, because $\phi > \pi_L^r$ (see Proof 9) the probability of screening $(1-\phi)$ is less than the probability of rationing, $(1-\pi_L^r)$. Recall that under screening only the non-screened projects are fully funded whereas under a rationing regime all funded



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projects are fully funded. The intuition is that under the screening regime not only are more low-risk projects funded but more low-risk projects get full funding.

The rationing and the screening contracts are summarized in Proposition 2.1.

**Proposition 2.1** *1. If $\beta^* < \beta_L$, then in equilibrium lenders offer the contract $C_L^r$*

*2. If $\beta^* > \beta_L$, then in equilibrium lenders offer the contract $C_L^s$*

*3. If $\beta^* = \beta_L$, then in equilibrium lenders are indifferent between offering $C_L^r$ or $C_L^s$*

*where $\beta^* = \frac{p_L - \varepsilon}{1+\gamma} Q \rho_{t+1} w_t$.*

*Proof See Proof 3*

Proposition 2.1 implies that whether the screening or the rationing contract prevails depends on the marginal product of capital $\rho_{t+1}$ and labour rate $w_t$. For high $\rho_{t+1}$ and $w_t$, the returns from investing are large, rationing is costly and thus screening dominates. Similarly, screening is more attractive the higher $Q$ or $p_L$ are and the lower the screening cost $\gamma$ is.

## 2.4 Imperfect screening

Section 2.3 determined the equilibrium contracts which the lenders offer under perfect information and reproduced the Bose-Cothren asymmetric information model. In order to induce self-selection the lenders can ration or screen the borrowers. The screening was assumed to be perfect in that the lender could identify the true type of the borrower with certainty.

However, in reality, screening technologies are arguably imperfect, the current credit crunch consisting of an obvious proof of that idea. Usually, the lender is able to draw only an imperfect inference about a borrower's type rather than identify the true type. For example, only some of the credit scoring techniques used to screen the creditworthiness of borrowers can directly estimate the probability of default.

However, despite much research from academics and industry, no single technique has been proven superior for predicting default in all circumstances.

The literature on informational asymmetries assumes that imperfect screening is particularly relevant for the screening of the high-risk borrowers. So, the bad-type agents are often and incorrectly identified as good ones but good-type agents are identified with certainty.[6] The idea behind this approach is that all borrowers appear to be of a low risk type, based on e.g. the disclosure to lenders of information about their type or information which lenders gather from active screening, until some information is obtained that points to the opposite.

In order to capture this idea we extend the above analysis by allowing for imperfect inference in the screening process of the high-risk borrowers. Specifically, we assume that if a borrower is the $H$ type, the lender will only be able to draw an imperfect inference about his true type whereas if a borrower is the $L$ type the lender identifies him as such with certainty. We use $\delta$ to identify the quality of the screening process i.e. how successfully a lender can obtain or interpret the information needed to decipher that a potential borrower is a high risk type. The screening quality is exogenous and $\delta \in [0, 1]$.[7]

Similarly to BC, we assume that the screening cost is defined as a resource cost $c$ proportional to the amount lent i.e. if $q^s_{lt}$ is the amount of the loan then the screening cost is $cq^s_{lt}$. The screening cost is exogenous and $c \in [0, \infty)$.[8]

It is worth noting that the Bose-Cothren model of perfect screening can be seen as a special case of our model since for $\delta = 1$, the lender can identify the type of the potential borrower with certainty. For any other value of $\delta$ the lender draws an imperfect inference about the type of the borrower.

Let $j = h,l$ denote the lender's inference about the type of the borrower. If the

[6] See e.g. Chemmanur and Fulghieri (1999) who use this information structure for firms wishing to raise external finance from venture capitalists or small investors in the IPO market.

[7] Another approach will be to endogenise the screening effort and solve for the optimum level of $\delta$. In this case the model will be a two stage game. We do not address this question. In section 7 we give a brief discussion of the effect of changes in $\delta$.

[8] The relationship between the quality of screening and the screening cost is not modeled. However, there is some discussion provided in Proof 5.

borrower is high risk, but pretends to be low-risk, the lender will identify him as $H$ type ($j = h$) with probability $\delta$ and as $L$ type ($j = l$) with probability $(1 - \delta)$. The lender can identify with certainty the type of a low-risk borrower. We define the conditional probabilities of inference given the true type of a borrower as:

$$\begin{aligned} p(l/L) &= 1 \\ p(h/L) &= 0 \\ p(l/H) &= (1-\delta) \\ p(h/H) &= \delta \end{aligned}$$

The conditional probabilities with respect to the true type of the borrower add up to one: $p(l/L) + p(h/L) = 1$ and $p(l/H) + p(h/H) = 1$.

Similarly to the case of perfect screening, the borrowers who declare themselves to be of type $H$ never get screened. There are no considerations of self-selection since a low-risk borrower has no incentive to be considered as high-risk. Moreover, the costly screening cannot further improve their expected payoff since they are being offered their first best contract. Thus, in an environment where lenders have the option of screening the borrowers, even if the screening process is imperfect, the contract offered to the $H$ type borrowers will not change i.e. the borrowers that declare themselves to be of type $H$ are offered their first-best contract $C_H$. However, since in a rationing regime the low-risk borrowers face a positive probability of being rationed, we will show that if screening results in a net gain for the low-risk borrowers, then there will exist a separating equilibrium where the rationing contract $C_L$ will be replaced by a screening contract of type $C_l^s = [(\phi_t, R_{lt}^n, q_{lt}^n, \pi_{lt}^n); ((1-\phi_t), R_{lt}^s, q_{lt}^s, \pi_{lt}^s)]$ (note that the subscripts of the quantity of the credit and the interest rate are now lower case letters i.e. the lender allocates a contract according to his imperfect inference about the type of the borrower rather than the true type). Thus, when a borrower denotes himself as an $L$ type borrower and the inference of the lender is $l$, the borrower is offered the contract $C_l^s$. However, if the inference is $h$, the borrower is punished by being denied a loan, similarly to BC. Figure 4 summarizes the different scenarios.[9]

[9] An alternative approach would be for the lender, acknowledging the imperfect nature of his

The timing of contracting is similar to that in Figure 3.

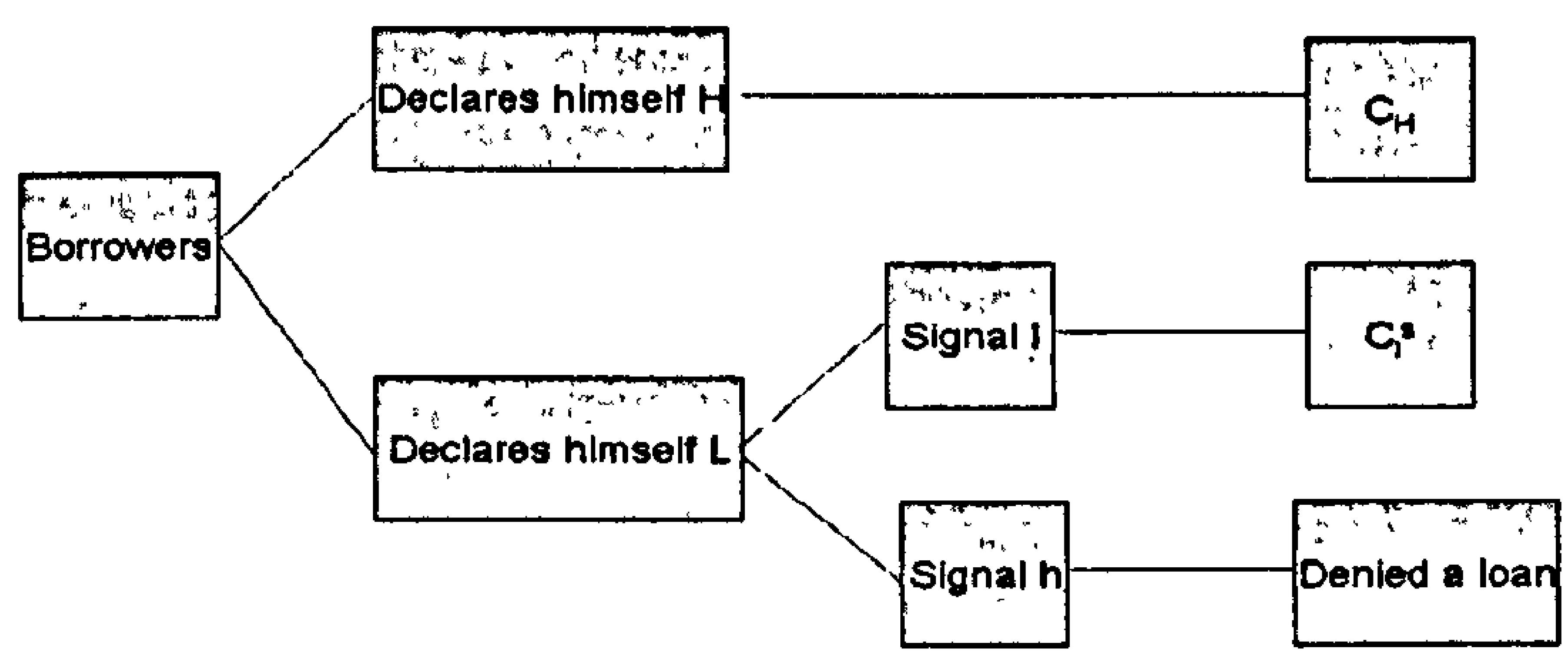


Figure 4

To simplify the analysis we focus on an economic environment where screening is compulsory for the borrowers who declare themselves as low risk. In other words, the probability of a borrower not being screened $\phi_t$ is now exogenous and equal to zero. So, the contract terms are simplified to $C_l^s = (R_{lt}^s, q_{lt}^s, \pi_{lt}^s)$. Notice the differences with the case of the perfect screening which we showed to be $C_L^s = [(\phi_t, R_{Lt}^n, q_{Lt}^n, \pi_{Lt}^n)\,;((1-\phi_t)\,, R_{Lt}^s, q_{Lt}^s)]$. First, the screening variable $\phi_t$ is dropped from the contract terms, since all borrowers who apply for a low risk type contract are now screened. Second, rationing is now probable when screening takes place. Since the inference $l$ does not warrant that the borrower is definitely the $L$ type, it is uncertain whether all borrowers who declare themselves as low-risk get funded i.e. the rationing variable $\pi_{lt}^s$ might not be unity.

Since competition leads lenders to offer the best break-even contract for each type, both types of borrowers will be offered the maximal contracts for them i.e. the best $R_{it}, q_{it}$ and $\pi_{it}$ among the set of contracts that satisfy the constraints of the model. So, similarly to the perfect screening case, the $H$ type borrowers receive

inference, to grant a loan but with "less preferential" terms to those borrowers whom he thinks are just mimicking the $L$ type. However, this case is beyond the scope of this chapter.

their first-best contract $C_H$ but $L$ type borrowers get a second-best contract. More specifically, lenders, who earn zero economic profit on each contract, will select those $R_{lt}^s, q_{lt}^s, \pi_{lt}^s$ that maximize the expected utility of the low risk type subject to their own zero profit condition, the incentive compatibility constraint of the high risk type and the feasibility constraint on the amount of the loan. As before, we assume that the participation constraints for the two types of borrowers and the incentive compatibility constraint of the low risk borrowers are not binding and thus can be ignored during the maximization process. To save on space we only give these constraints in the Appendix where we also verify that there are not binding for the contract terms of the derived screening contract. Thus, the problem is:

Maximize

$$EP_l\left(C_l^s\right) = \pi_{lt}^s p_L \left(Q\rho_{t+1} - R_l^s\right) q_{lt}^s + \left(1 - \pi_{lt}^s\right)\beta_L$$

subject to

$$\left(Q\rho_{t+1} - \frac{Q\varepsilon\rho_{t+1}}{p_H}\right) w_t \geq \pi_{lt}^s \left(1 - \delta\right) \left(Q\rho_{t+1} - R_l^s\right) q_{lt}^s \tag{2.16}$$

$$\pi_{lt}^s q_{lt}^s R_l^s p_L = \pi_{lt}^s q_{lt}^s \left(1 + c\right) Q\varepsilon\rho_{t+1} \tag{2.17}$$

$$q_{lt}^s \leq w_t - q_{lt}^s c \tag{2.18}$$

The incentive compatibility constraint of the high risk type (2.16) shows that although there is no difference to the expected payoff when he is truth-telling, his expected payoff is affected by the quality of screening when he mimics a low-risk borrower. Expression (2.17) has the following interpretation. The left hand side gives the interest income the lender will receive by granting a loan in the case where his screening inference is $l$. Of course, the probability of yielding the return depends on the real entrepreneurial ability $p_L$. The expected payoff of the lender should be equal to the opportunity cost of the loan. In other words, the expected return of the amount $q_{lt}^s\left(1 + c\right)$ should be the same as the safe return he would otherwise get.

Finally, expression (2.18) shows that the amount of the loan $q_{lt}^{s}$ is restricted by the lenders' wage after accounting for the screening cost.

We find that as long as (2.7) holds, two new and mutually exclusive screening contracts $C_l^{s_1}$ and $C_l^{s_2}$ emerge:

$$C_l^{s_1} = \left(R_l^{s_1}, q_{lt}^{s_1}, \pi_{lt}^{s_1}\right) = \left(\frac{(1+c)\,Q\varepsilon\rho_{t+1}}{p_L}, \frac{w_t}{1+c}, \frac{\left(1-\frac{\varepsilon}{p_H}\right)(1+c)}{\left(1-\delta^{s_1}\right)\left(1-\frac{(1+c)\varepsilon}{p_L}\right)}\right)$$

$$C_l^{s_2} = \left(R_l^{s_2}, q_{lt}^{s_2}, \pi_{lt}^{s_2}\right) = \left(\frac{(1+c)\,Q\varepsilon\rho_{t+1}}{p_L}, \frac{w_t}{(1+c)}, 1\right)$$

We give the detailed maximization in the Appendix (see Proof 4) but the dual screening contract must be discussed here. A common formula for the non-rationing probability lies behind the contracts $C_l^{s_1}$ and $C_l^{s_2}$:

$$\pi_{lt} = \frac{\left(1-\frac{\varepsilon}{p_H}\right)(1+c)}{(1-\delta)\left(1-\frac{(1+c)\varepsilon}{p_L}\right)} \tag{2.19}$$

The RHS of (2.19) cannot be uniquely signed. Furthermore, it is possible that it takes values outside the range zero to one for some values of the parameters. The two screening contracts are defined as follows. For $C_l^{s_1}$ the RHS of (2.19) takes any value in the range $(0,1)$ but is equal to one for $C_l^{s_2}$. This implies that $C_l^{s_1}$ and $C_l^{s_2}$ differ at the screening quality $\delta$ and/or the relevant screening cost $c$ (since we assume that $\varepsilon$, $p_H$ and $p_L$ are the same under all regimes i.e. they don't vary within a country, across countries and over time). We make a further assumption that the two screening contracts $C_l^{s_1}$ and $C_l^{s_2}$ share the same level of screening costs but have different screening qualities, specifically $\delta^{s_1} < \delta^{s_2}$ (see Proof 5). This assumption is very intuitive. Recall that the screening contract $C_l^{s_1}$ has a positive probability of rationing whereas there is no rationing in $C_l^{s_2}$. Hence, it is reasonable that if the screening cost is the same under $C_l^{s_1}$ and $C_l^{s_2}$, the lower quality of screening $\delta^{s_1}$ leads lenders to ration more borrowers.

Hence, for the different values $\pi_{lt}$ (as given by (2.19)), the equilibrium contracts are described by Proposition 2.2:

**Proposition 2.2**

| *"Developed" Economy* ($p_L > (1+c)\,\varepsilon$) | | |
|---|---|---|
| *Conditions* | | *Equilibrium Contract* |
| $\pi_{lt} = 0$ | $(\beta^r > \beta_L)$ | $C_L^r$ |
| $0 < \pi_{lt} < 1$ | $\beta^{s_1} < \beta_L$ | $C_L^r$ |
| | $\beta^{s_1} > \beta_L$ | $C_l^{s_1}$ |
| | $\beta^{s_1} = \beta_L$ | *Indifferent between* $C_l^{s_1}$, $C_L^r$ |
| $\pi_{lt} = 1$ | $\beta^{s_2} < \beta_L$ | $C_L^r$ |
| | $\beta^{s_2} > \beta_L$ | $C_l^{s_2}$ |
| | $\beta^{s_2} = \beta_L$ | *Indifferent between* $C_l^{s_2}$, $C_L^r$ |
| $\pi_{lt} > 1$ | $(\beta^r > \beta_L)$ | $C_L^r$ |

| *"Undeveloped" Economy* ($p_L < (1+c)\,\varepsilon$) | | |
|---|---|---|
| $\pi_{lt} < 0$ | $(\beta^r > \beta_L)$ | $C_L^r$ |

*where*

$$\beta^r = Q\rho_{t+1}w_t\,(p_L - \varepsilon)$$
$$\beta^{s_1} = Q\rho_{t+1}w_t\frac{\delta^{s_1}(p_L-(1+c)\varepsilon)(p_L-\varepsilon)}{c(p_L-\delta^{s_1}\varepsilon)+\delta^{s_1}(p_L-\varepsilon)}$$
$$\beta^{s_2} = Q\rho_{t+1}w_t\left(\frac{1}{(1+c)}+\frac{\varepsilon}{p_H}-\frac{\varepsilon}{p_L}-1\right)\frac{p_L p_H(p_L-\varepsilon)}{\varepsilon(p_L-p_H)}$$
$$\pi_{lt} = \frac{\left(1-\frac{\varepsilon}{p_H}\right)(1+c)}{(1-\delta)\left(1-\frac{(1+c)\varepsilon}{p_L}\right)}$$

*Proof See Proof 4*

Proposition 2.2 makes apparent that the assumption $p_L \lesseqgtr (1+c)\,\varepsilon$ is crucial and thus it should be further discussed. To understand possible economic interpretations of that expression we first need to discuss each of the parameters involved. To interpret $\varepsilon$ it should be recalled that an investment project converts one unit of output to $Q$ units of $k_{t+1}$ (with probability $p_i$) whereas home technology converts one unit of output to $Q\varepsilon$ units of $k_{t+1}$ where $\varepsilon \in (0,1)$. Hence, $\varepsilon$ can be perceived as the ratio of the safe to the risky rate of return (if $\varepsilon \approx 1$ the home technology output is similar to the investment project output). A reasonable interpretation of the safe rate is the rate of a governmental bond. In that case many economic and sociopolitical variables might affect its value. Similarly, the values of investors' probability of success $p_L$ and the screening cost $c$ might be influenced by e.g. the general infrastructure of an economy, the institutions, the rule of law etc. Bearing such interpretations in mind we can define the case $p_L > (1+c)\,\varepsilon$ as describing a "developed" economy. So, in a "developed" country the screening cost is relatively small or the investment projects are to a substantial extent more appealing than home technology (i.e. $p_L >> \varepsilon$) or lenders' home technology's output is relatively low ($\varepsilon$ is small). Similarly, if $p_L < (1+c)\,\varepsilon$ then the economy under question is an "undeveloped" one.[10]

It is reasonable to expect that a developed economy will be characterized by a developed financial market. Similarly, it is more probable that the financial market will be less developed in an undeveloped economy. So, we will be using the two terms, economy and financial markets, interchangeably.

The variables $\beta^i$ are the switching or indifference points for the borrowers between two different contracts. So, $\beta^{s_1}$ gives the indifference point between $C_l^{s_1}$ and $C_L^r$, $\beta^{s_2}$ gives the indifference point between  and $C_L^r$ and $\beta^r$ defines the indifference point between $C_L^r$ and home technology. Proof 4 also shows that they can be ranked as $\beta^{s_1} < \beta^{s_2} < \beta^r$.

The main predictions of our model can be outlined as follows. When screening is imperfect, $H$ type borrowers always get their first-best contract but $L$ type borrowers get a second-best contract. The contract offered to $L$ type borrowers differ according to the level of development of the economy. More specifically, we find that in an undeveloped economy the screening regime is not an option for the low risk borrowers i.e. the lenders never offer a screening contract (remember that it is the borrowers who decide whether the rationing or the screening contract is optimal for them according

[10]One could argue that the screening cost is relatively high in developed countries due to the size of the firms, the complexity of the corporate form, the degree of sophistication of accounting methods etc. However, big firms and conglomerates can raise capital through other means such as issuing bonds. Thus, they cannot be seen as the typical case of firms whose financing problem is addressed in this paper.

to their expected payoff but the terms of the contract should satisfy the zero profit condition of the lenders). In a developed economy things are more complicated. A lender can offer three different contracts to $L$ type borrowers, the rationing contract $C_L^r$ or one of the two screening contracts $C_l^{s1}$ or $C_l^{s2}$. The two screening contracts differ by the probability of non-rationing ($\pi_{lt}^{s2}$ or $\pi_{lt}^{s1}$) which in turn differs by the quality of screening lenders have used in the screening process ($\delta^{s1}$ or $\delta^{s2}$). So, summarizing, when $\pi_{lt} \leq 0$ or $\pi_{lt} > 1$ the rationing contract is the only contract offered to low-risk borrowers whereas when $0 < \pi_{lt} \leq 1$ the lenders might offer the rationing or a screening contract. In conclusion, allowing screening to be imperfect leads to substantially different results than the perfect screening hypothesis of BC who reached a strong result where first, the contracts offered are invariant to the level of development of the economy and second, there is a unique screening contract offered to the low risk borrowers.

It is worth noting that $\beta_L$ is the critical parameter concerning the participation or not of the borrowers. In other words, $\beta_L$ is a measure of the minimum rents that must be offered to induce $L$ type borrowers to participate. A reasonable interpretation of these minimum rents is the wage an entrepreneur can get if does not materialize his investment project. A high outside wage might lead to market collapse for low risk borrowers (a possibility precluded by the assumptions of our model) whereas a low outside wage leads to certain participation. Moreover, how $\beta_L$ compares to $\beta^{s1}$, $\beta^{s2}$ is critical for defining whether the expected payoff from screening is higher than the expected payoff from rationing in both developed and undeveloped economies and thus for defining whether the rationing or the screening contract is offered by the lenders.

Similarly to the perfect screening case, the form of equilibrium contract depends on the marginal product of capital $\rho_{t+1}$ and the labour rate of return $w_t$. For large values of $w_t$ and $\rho_{t+1}$, the returns from investing are large, rationing is costly and thus screening dominates. Similarly, screening prevails for high quality of screening $\delta^{s1}$ and low screening cost $c$.

In what follows we compare the equilibrium contracts under imperfect screening with the ones under a rationing regime $C_L^r$ or perfect screening $C_L^s$. The interest rate, when screening is imperfect and compulsory for the borrowers that claim to be low risk, is higher than under a rationing regime. So, both $R_l^{s1}$ and $R_l^{s2}$ are higher than $R_{Lt}^r$ for any non zero screening cost $(\frac{(1+c)Q\varepsilon\rho_{t+1}}{p_L} > \frac{Q\varepsilon\rho_{t+1}}{p_L})$. However, $R_l^{s1}$ and $R_l^{s2}$ are higher than $R_{Lt}^s$ for a high screening cost only $(\frac{(1+c)Q\varepsilon\rho_{t+1}}{p_L} > \frac{Q\varepsilon\rho_{t+1}}{p_L\phi})$.

Note that since screening entails the expense of positive resources and is now compulsory, none of the low-risk projects gets full funding. Recall that this is not the case under rationing or perfect screening since all non rationed and all non screened low-risk borrowers respectively get full funding.

We next look at the rationing probability. Lenders find it optimal to mix screening with rationing when they offer the $C_l^{s1}$, contrary to the case of perfect screening. So, when screening is imperfect, fewer low-risk projects are funded than if screening were perfect $(\pi_L^s(1-\phi) + \pi_L^n\phi > \pi_l^s \Rightarrow 1 > \frac{\left(1-\frac{\varepsilon}{p_H}\right)(1+c)}{(1-\delta^{s1})\left(1-\frac{(1+c)\varepsilon}{p_L}\right)})$. Finally, for the contract $C_l^{s2}$ it is easy to see that $\pi_{lt}^{s2} = \pi_{Lt}^s > \pi_L^r$ and in *Proof 6* we show that $\pi_{lt}^{s1} > \pi_{Lt}^r$.

A final discussion point can be added about the comparative statics of the quality of screening and more specifically the critical value of $\delta$ which tips an economy from screening into rationing. An interesting result emerges from the case of $\pi_{lt} = 1$. The appendix shows that the critical value of $\delta$ does not anymore depend on the screening cost $c$ or alternatively that the critical value of $c$ which tips an economy from screening into rationing is independent of $\delta$ (see *Proof 7*). The implication of such finding is that there are cases where the model presented in this study can be possibly simplified by dropping $c$ or $\delta$. Further research is needed to check whether one of the two parameters and which one drives the results when the imperfect and compulsory screening is matched with certainty of granting of a loan.

## 2.5 The dynamic path of capital

Recall that the economy consists of an infinite sequence of two-period-lived overlapping generations. All cohorts are assumed to be of equal size. Half of each cohort's agents are borrowers and half are lenders. All agents are endowed with one unit of labour at the first period of their lives and all wish to consume in the second period. Young lenders offer their labour to the competitive market, earning the wage $w_t$, and then decide whether to give their proceedings as a loan to a borrower or use them according to their home production technology. Young borrowers use their labour endowment to run their investment project if they get a loan or to run their home technology if they are denied a loan. At the second period all borrowers become entrepreneurs. Entrepreneurs can hire labour from the young lenders at wage $w_{t+1}$ and capital from the old lenders at rate $\rho_{t+1}$. It is worth reminding that there are two ways to produce time $t+1$ capital: first, according to the firm production function where one unit of time $t$ output is converted to $Q$ units of time $t+1$ capital and second, according to the home production of the lenders where one unit of time $t$ output is converted to $Q\varepsilon$ units of time $t+1$ capital. Finally, we assume that the firms produce time $t+1$ output according to the exogenous growth function $y_{t+1} = k_{t+1}^{\theta} L_{t+1}^{1-\theta}$.

There is complete factor mobility and hence in equilibrium all firms employ an equal amount of labour. Since all borrowers become firm operators the number of firms per capita is 0.5. The per capita supply of labour is restricted to the number of those agents called lenders i.e. 0.5 (since borrowers who are denied credit are excluded from selling their labour from the timing of events). Hence, at each time period employees per firm are $labour/firm \equiv L_t = 1$.

Since the consumption of both the lenders and the borrowers in the second period depends on the capital accumulation realized in the first period, it is important to describe the capital accumulation process in detail. To derive the general equilibrium, we have to look at the growth path and steady states of the economy under the different rationing and screening regimes. There are five pairs of equilibrium contracts: the high risk borrowers always get their first best contract (the perfect information contract $C_H$) but the contract of the low risk borrowers differs. In what follows, we derive the capital accumulation paths for these five pairs of equilibrium contracts and express them in the form $k_{t+1} = ak_t^{\theta}$. The section concludes with a number of propositions which describe how the resulting capital paths compare to each other.

**Case 1:** $(C_H, C_L^r)$

None of the borrowers is screened. All high-risk borrowers obtain loans, but some low-risk borrowers are rationed. The capital stock at the second period comes from the successful high-risk borrowers, the low-risk borrowers who were not rationed but were successful and from those lenders that converted their wages into capital after rationing some low-risk borrowers. The aggregate capital stock is:

$$\begin{aligned} K_{t+1}^r &= 0.5\lambda p_H Q w_t + 0.5(1-\lambda) p_L \pi_L^r Q w_t + 0.5(1-\lambda)(1-\pi_L^r) Q \varepsilon w_t \\ &= (\lambda p_H + (1-\lambda) p_L \pi_L^r + (1-\lambda)(1-\pi_L^r)\varepsilon) 0.5 Q w_t \end{aligned}$$

It is apparent that we assume full depreciation of the capital each period (if capital depreciates only partially, there would be another term on the right hand side of the above equation reflecting the fraction of the un-depreciated capital from period $t$ and an additional market would be needed to allow the un-depreciated capital to be traded between generations).

Since there are 0.5 firms per capita, the per firm capital stock is:

$$k_{t+1}^r = (\lambda p_H + (1-\lambda) p_L \pi_L^r + (1-\lambda)(1-\pi_L^r)\varepsilon) Q w_t \tag{2.20}$$

The wage rate at time $t$ is:

$$\frac{\partial y_t}{\partial L_t} = w_t = (1-\theta) k_t^\theta L_t^{-\theta}$$

Since $L_t = 1$ then

$$w_t = (1-\theta) k_t^\theta \tag{2.21}$$

Substituting (2.21) into (2.20) we get:

$$k_{t+1}^{r} = \left(\lambda p_H + (1-\lambda)\, p_L \pi_L^r + (1-\lambda)\,(1-\pi_L^r)\,\varepsilon\right) Q\,(1-\theta)\, K_t^{\theta} \equiv A k_t^{\theta} \tag{2.22}$$

where $A = \left(\lambda p_H + (1-\lambda)\, p_L \pi_L^r + (1-\lambda)\,(1-\pi_L^r)\,\varepsilon\right) Q\,(1-\theta)$. Equation (2.22) describes the dynamic path of capital. At the steady state $k_{t+1}^r = k_t$ and so from (2.22) the steady state quantity of capital is:

$$k_{ss}^{r} = A^{1/(1-\theta)} \tag{2.23}$$

Note that $\frac{\partial A}{\partial \pi_{Lt}} = \left((1-\lambda)\,(p_L - \varepsilon)\right) Q\,(1-\theta) > 0$, which implies that a decrease in credit rationing shifts the capital accumulation curve up and thus leads the economy to a higher steady-state capital stock.

**Case 2:** $(C_H, C_L^s)$

All low-risk and high-risk borrowers obtain loans and a fraction of low-risk borrowers is screened. The capital stock at $t+1$ comes from the high-risk borrowers that were successful in running their investment project, from the low-risk borrowers who where screened and were successful in their investment and from the low-risk borrowers who where not screened and were successful in their investment. Thus, the per firm capital stock is:

$$k_{t+1}^{s} = Q\,(1-\theta)\, k_t^{\theta} \left(\lambda p_H + (1-\lambda)\, p_L \frac{1+\gamma\phi}{1+\gamma}\right) = B k_t^{\theta} \tag{2.24}$$

where $B = Q\,(1-\theta)\left(\lambda p_H + (1-\lambda)\, p_L \frac{1+\gamma\phi}{1+\gamma}\right)$. Equation (2.24) describes the dynamic path of capital. The steady state quantity of capital is given by:

$$k_{ss}^{s} = B^{1/(1-\theta)} \tag{2.25}$$

Note that $\frac{\partial B}{\partial \gamma} < 0$, which implies that a decrease in the screening cost shifts the capital accumulation curve up. Moreover, $\frac{\partial B}{\partial \phi} > 0$ and thus an increase in the probability of screening $(1-\phi)$ leads the economy to a lower $k^{s}_{ss}$.[11]

A comparison of (2.22),(2.23), (2.24) and (2.25) shows that the screening and the rationing contracts lead to different capital accumulation paths and steady states. The distinction between the two paths is described by Proposition 2.3.

**Case 3:** $\left(C_H, C_l^{s1}\right)$

The capital stock in the second period comes from the successful high-risk borrowers, from the low-risk borrowers who where screened, not rationed and successful in their investment. Moreover, there are some lenders that converted their wages into capital after rationing some low-risk borrowers. Note that this last implies a deadweight loss $0.5\,(1-\lambda)\left(1-\pi_{lt}^{s1}\right)Qw_t c$ which was not present in the case of perfect screening. Thus, the per firm capital stock is:

$$k_{t+1}^{s1} = Q\,(1-\theta)\,k_t^{\theta}\left(\lambda p_H + (1-\lambda)\,p_L\pi_{lt}^{s1}\frac{1}{1+c} + (1-\lambda)\left(1-\pi_{lt}^{s1}\right)\varepsilon\frac{1}{1+c}\right) = Dk_t^{\theta} \tag{2.26}$$

where $D = Q\,(1-\theta)\left(\lambda p_H + (1-\lambda)\,p_L\pi_{lt}^{s1}\frac{1}{1+c} + (1-\lambda)\left(1-\pi_{lt}^{s1}\right)\varepsilon\frac{1}{1+c}\right)$. Equation (2.26) describes the dynamic path of capital. At the steady state $k_{t+1}^{s1} = k_t$ and so the steady state quantity of capital is:

$$k_{ss}^{s1} = D^{1/(1-\theta)} \tag{2.27}$$

An increase in the screening cost can have positive or negative impact on $k_{t+1}^{s1}$. This result emerges from the fact that $k_{t+1}^{s1}$ depends both negatively and directly on $c$ but also positively and indirectly through $\pi_{lt}^{s1}$. In other words, a higher screening cost implies more resources spent but a higher probability of granting a loan. This trade-off was not present in the case of perfect screening (or for $\left(C_H, C_l^{s2}\right)$) since in that case low risk borrowers get funded with certainty. Finally, $\frac{\partial D}{\partial \delta^{s1}} > 0$ and thus an increase in the quality of screening shifts the capital accumulation curve up.

[11] The analytical derivation of the dynamic paths of all the cases as well as the relevant derivatives for the comparative statics analysis for all the cases are given in Proof 7.

Case 4: $\left(C_H, C_l^{s2}\right)$

The capital stock in the second period comes from the successful high-risk borrowers $0.5\lambda p_H$ and from the low-risk borrowers who where screened and successful in their investment. Thus, the per firm capital stock is:

$$k_{t+1}^{s2} = Q\left(1-\theta\right) k_t^{\theta} \left(\lambda p_H + \left(1-\lambda\right) p_L \frac{1}{\left(1+c\right)}\right) = F k_t^{\theta} \tag{2.28}$$

where $F = Q\left(1-\theta\right)\left(\lambda p_H + \left(1-\lambda\right) p_L \frac{1}{(1+c)}\right)$. Equation (2.28) describes the dynamic path of capital. At the steady state $k_{t+1}^{s2} = k_t$ and so the steady state quantity of capital is:

$$k_{ss}^{s2} = F^{1/(1-\theta)} \tag{2.29}$$

Consistently with the above cases, we find that $\frac{\partial F}{\partial c} < 0$ and $\frac{\partial F}{\partial \delta^{s2}} > 0$, implying that a decrease of the screening cost or an increase in the quality of screening shifts the capital accumulation curve up.

Case 5: $\left(C_H, \text{Home Technology}\right)$

There is no screening contract offered to low risk borrowers. The capital stock at the second period comes from the successful high-risk borrowers and from the lenders that converted their wages into capital after rationing all low-risk borrowers. We assume that the lenders can foresee that for the given $\delta$ there is no $\pi_{lt}^{s}$ that satisfies the constraints of the model and thus no screening takes place. Thus, the per firm capital stock is:

$$k_{t+1}^{s3} = Q\left(1-\theta\right) k_t^{\theta} \left(\lambda p_H + \left(1-\lambda\right)\varepsilon\right) = G k_t^{\theta} \tag{2.30}$$

where $G = Q\left(1-\theta\right)\left(\lambda p_H + \left(1-\lambda\right)\varepsilon\right)$. Equation (2.30) describes the dynamic path of capital. We find that $\frac{\partial G}{\partial c} = 0$ which implies that the level of the screening cost is irrelevant to whether the economy will move to a higher capital accumulation path. At the steady state $k_{ss}^{s3} = k_t$ and so the steady state quantity of capital is:

$$k_{ss}^{s3} = G^{1/(1-\theta)}$$

**Proposition 2.3** *When screening is perfect, the screening contract yields a higher capital accumulation path and steady-state level of capital per firm than the rationing contract. That is, for a given $k_t$, $k_{t+1}^{s} > k_{t+1}^{r}$ and hence $k_{ss}^{s} > k_{ss}^{r}$.*

*Proof See Proof 9*

**Proposition 2.4** *When screening is imperfect and some low-risk borrowers are rationed, the screening contract might yield a lower or higher capital accumulation path and steady-state level of capital per firm than the rationing contract. That is, for a given $k_t$, $k_{t+1}^{s1} > k_{t+1}^{r}$ and hence $k_{ss}^{s1} > k_{ss}^{r}$ or $k_{t+1}^{s1} < k_{t+1}^{r}$ and hence $k_{ss}^{s1} < k_{ss}^{r}$.*

*Proof See Proof 10*

**Proposition 2.5** *When screening is imperfect and no low-risk borrowers are rationed, the screening contract yields a higher capital accumulation path and steady-state level of capital per firm than the rationing contract. That is, for a given $k_t$, $k_{t+1}^{s2} > k_{t+1}^{r}$ and hence $k_{ss}^{s2} > k_{ss}^{r}$.*

*Proof See Proof 11*

**Proposition 2.6** *When screening is imperfect, the screening contract where some low-risk borrowers are rationed yields a lower capital accumulation path and steady-state level of capital per firm than the screening contract where no low-risk borrowers are rationed. That is, for a given $k_t$, $k_{t+1}^{s2} > k_{t+1}^{s1}$ and hence $k_{ss}^{s2} > k_{ss}^{s1}$.*

*Proof See Proof 12*

**Proposition 2.7** *When screening is imperfect and all low-risk borrowers are rationed, the screening contract yields a lower capital accumulation path and steady-state level of capital per firm than the rationing contract. That is, for a given $k_t$, $k^{s3}_{t+1} > k^r_{t+1}$ and hence $k^{s3}_{ss} > k^r_{ss}$.*

*Proof See Proof 13*

Proposition 2.3 summarizes the results of BC i.e. the case of perfect screening. Figure 5 depicts the dynamic capital paths where Path $r$ corresponds to the pair $(C_H, C^r_L)$ and Path $s$ corresponds to the pair $(C_H, C^s_L)$.

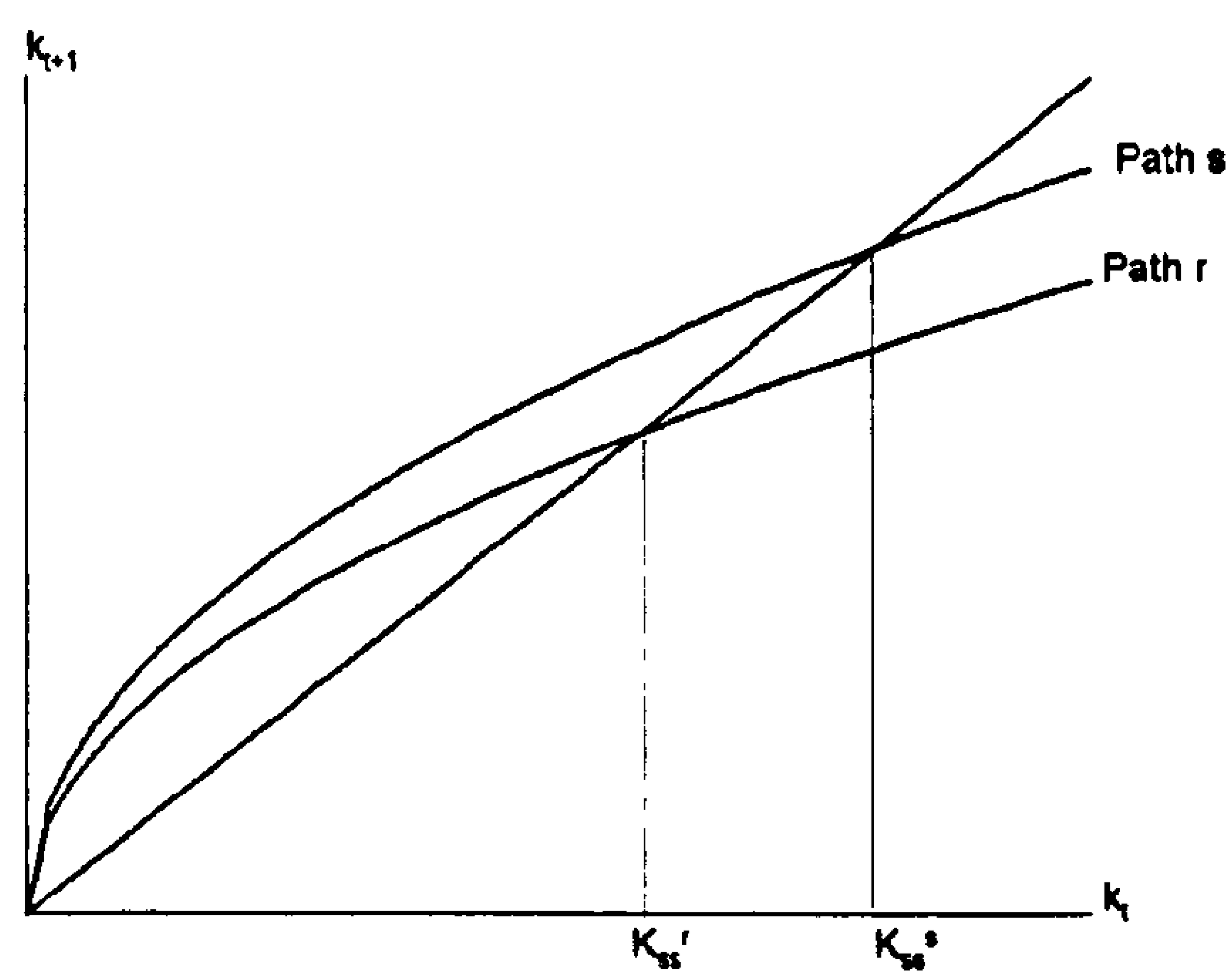


Figure 5

When screening is assumed to be imperfect, the picture is more complicated. Path $s_1$ corresponds to the pair $(C_H, C_l^{s_1})$, Path $s_2$ corresponds to the pair $(C_H, C_l^{s_2})$ and Path $s_3$ corresponds to the pair $(C_H, \text{Home Technology})$. Propositions 2.4 to 2.7 show that Path $s_2$ is always the highest dynamic path, Path $s_3$ is always the lowest but there are two possible rankings depending on the relative position of Path $s_1$ and Path $r$. The two cases are depicted by Figures 6 and 7.[12]

[12] We refrain from comparing the perfect screening dynamic path to the imperfect screening ones since the focal point of our analysis is the comparison of the different paths under imperfect screening.

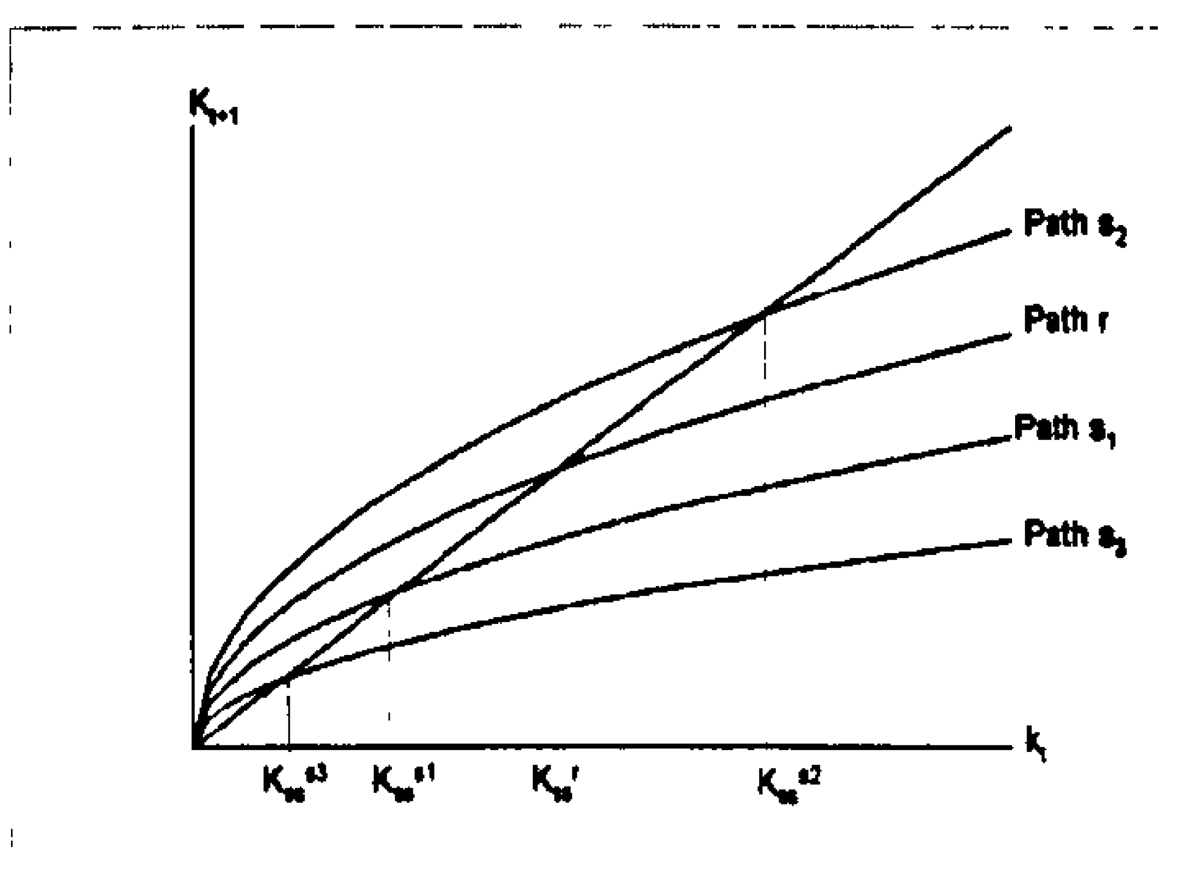


Figure 6

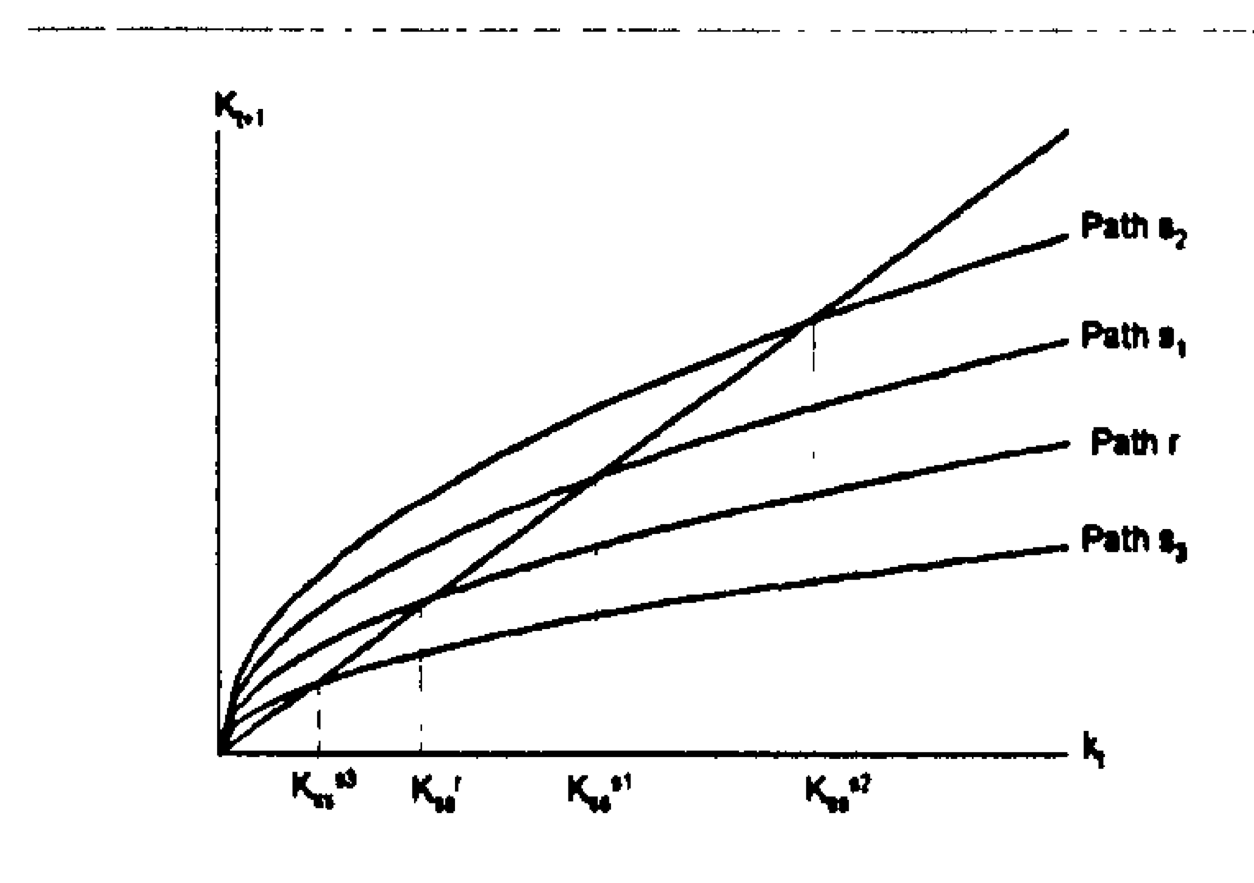


Figure 7

## 2.6 Equilibrium contracts and capital dynamics

We have seen that although in an undeveloped economy only rationing can be used to separate borrowers, the picture is more complicated in developed economies as screening can also be used to separate borrowers. So, we need to understand which regime prevails at equilibrium in a developed country.

Proposition 2.2 shows that whether $C_L^r$ or $C_l^{s_1}$ or $C_l^{s_2}$ prevails in a developed economy depends on $\beta^{s_1}$ and $\beta^{s_2}$ which in turn depend on the marginal products of capital and labour i.e. on $\rho_{t+1}$ and $w_t$. In other words, the contract's form depends on $k_t$ and $k_{t+1}$. However, the time $t+1$ capital stock $k_{t+1}$ and thus its marginal product $\rho_{t+1}$ depend on which contract was offered at time $t$. Hence, it is obvious that there is a mutual dependency between the equilibrium capital stock and contracting regime in developed economies.

To address the joint evolution of the equilibrium capital stock and contracting regime in developed economies, we need to calculate the marginal product of $k_{t+1}$ under the three different contracts. Note that there is not going to be any reference to the regime where no screening contract is offered to low risk borrowers (Dynamic



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path $k^{s_3}_{t+1}$) as it is always dominated by the rationing contract (see Proof 4). Thus, if the time $t$ equilibrium contract is $C^r_L$,$C^{s_1}_l$, $C^{s_2}_l$ then the marginal product of $k_{t+1}$ is respectively:

$$\rho^r_{t+1} = \frac{\partial y}{\partial k^r_{t+1}} = \frac{\partial \left(k^r_{t+1}\right)^\theta L^{1-\theta}_{t+1}}{\partial k^r_{t+1}} = \theta \left(k^r_{t+1}\right)^{\theta-1} = \theta \left(Ak^\theta_{t+1}\right)^{\theta-1} \tag{2.31a}$$

$$\rho^{s_1}_{t+1} = \frac{\partial y}{\partial k^{s_1}_{t+1}} = \frac{\partial \left(k^{s_1}_{t+1}\right)^\theta L^{1-\theta}_{t+1}}{\partial k^{s_1}_{t+1}} = \theta \left(k^{s_1}_{t+1}\right)^{\theta-1} = \theta \left(Dk^\theta_{t+1}\right)^{\theta-1} \tag{2.31b}$$

$$\rho^{s_2}_{t+1} = \frac{\partial y}{\partial k^{s_2}_{t+1}} = \frac{\partial \left(k^{s_2}_{t+1}\right)^\theta L^{1-\theta}_{t+1}}{\partial k^{s_2}_{t+1}} = \theta \left(k^{s_2}_{t+1}\right)^{\theta-1} = \theta \left(Fk^\theta_{t+1}\right)^{\theta-1} \tag{2.31c}$$

It is also necessary to estimate the value of the switching points between rationing and screening at the equilibrium values of the marginal products of capital and labour. We define:

$$\beta^*_{r_1} = Q\rho^r_{t+1}w_t \frac{\delta^{s_1}\left(p_L - (1+c)\varepsilon\right)(p_L - \varepsilon)}{c\left(p_L - \delta^{s_1}\varepsilon\right) + \delta^{s_1}\left(p_L - \varepsilon\right)} \tag{2.32a}$$

$$\beta^*_{s_1} = Q\rho^{s_1}_{t+1}w_t \frac{\delta^{s_1}\left(p_L - (1+c)\varepsilon\right)(p_L - \varepsilon)}{c\left(p_L - \delta^{s_1}\varepsilon\right) + \delta^{s_1}\left(p_L - \varepsilon\right)} \tag{2.32b}$$

$$\beta^*_{r_2} = Q\rho^r_{t+1}w_t \left(\frac{1}{(1+c)} + \frac{\varepsilon}{p_H} - \frac{\varepsilon}{p_L} - 1\right) \frac{p_L p_H \left(p_L - \varepsilon\right)}{\varepsilon\left(p_L - p_H\right)} \tag{2.32c}$$

$$\beta^*_{s_2} = Q\rho^{s_2}_{t+1}w_t \left(\frac{1}{(1+c)} + \frac{\varepsilon}{p_H} - \frac{\varepsilon}{p_L} - 1\right) \frac{p_L p_H \left(p_L - \varepsilon\right)}{\varepsilon\left(p_L - p_H\right)} \tag{2.32d}$$

which are the expressions for $\beta^{s_1}$ and $\beta^{s_2}$ from Proposition 2.2. Substituting the values $w_t$, $\rho^r_{t+1}$, $\rho^{s_1}_{t+1}$ and $\rho^{s_2}_{t+1}$ from (2.21), $(2.31a-d)$ into $(2.32a-d)$ we obtain:

$$\beta^*_{r_1} = \frac{\delta^{s_1}\left(p_L - (1+c)\varepsilon\right)(p_L - \varepsilon)}{c\left(p_L - \delta^{s_1}\varepsilon\right) + \delta^{s_1}\left(p_L - \varepsilon\right)} Q\left(1-\theta\right)\theta k_t^{\theta^2} A^{\theta-1} \tag{2.33a}$$

$$\beta^*_{s_1} = \frac{\delta^{s_1}\left(p_L - (1+c)\varepsilon\right)(p_L - \varepsilon)}{c\left(p_L - \delta^{s_1}\varepsilon\right) + \delta^{s_1}\left(p_L - \varepsilon\right)} Q\left(1-\theta\right)\theta k_t^{\theta^2} D^{\theta-1} \tag{2.33b}$$

$$\beta^*_{r_2} = \left(\frac{1}{(1+c)} + \frac{\varepsilon}{p_H} - \frac{\varepsilon}{p_L} - 1\right) \frac{p_L p_H \left(p_L - \varepsilon\right)}{\varepsilon\left(p_L - p_H\right)} Q\left(1-\theta\right)\theta k_t^{\theta^2} A^{\theta-1} \tag{2.33c}$$

$$\beta^*_{s_2} = \left(\frac{1}{(1+c)} + \frac{\varepsilon}{p_H} - \frac{\varepsilon}{p_L} - 1\right) \frac{p_L p_H \left(p_L - \varepsilon\right)}{\varepsilon\left(p_L - p_H\right)} Q\left(1-\theta\right)\theta k_t^{\theta^2} F^{\theta-1} \tag{2.33d}$$

Propositions 2.4 to 2.7 have shown that there are two possible rankings of the dynamic paths depending on the relative position of $k_{t+1}^{s1}$ and $k_{t+1}^{r}$. So, in order to understand which regime prevails at equilibrium in a developed country, we examine the two cases separately.

### 2.6.1 Path $s_1$ < Path $r$

The production function exhibits diminishing returns to capital and thus $\rho_{t+1}^{s1} > \rho_{t+1}^{r} > \rho_{t+1}^{s2}$. Since $\beta_{r_1}^*$, $\beta_{s_1}^*$, $\beta_{r_2}^*$ and $\beta_{s_2}^*$ are increasing functions of $k_t$ and $(\theta - 1) < 0$ we obtain that $\beta_{r_1}^* < \beta_{s_1}^*$ as $A > D$ and $\beta_{r_2}^* > \beta_{s_2}^*$ as $A < F$. Moreover, $\beta_{s_1} < \beta_{s_2}$ (see *Proof 12*). Thus, the ranking of the $\beta^*$ functions is $\beta_{r_1}^* < \beta_{s_1}^* < \beta_{s_2}^* < \beta_{r_2}^*$. In Figure 8 we plot the $\beta^*$ functions of $(2.33a - d)$ and an arbitrary $\beta_L$. Depending on how the $\beta^*$ functions compare to $\beta_L$ there is a different equilibrium pair of contracts. It is worth reminding that since the Paths $s_1$ and $s_2$ depend on the exogenous value of the quality of screening, there is no switching between the two screening regimes and we only consider switching from each screening path to the rationing path. Thus, we need to consider the following cases:

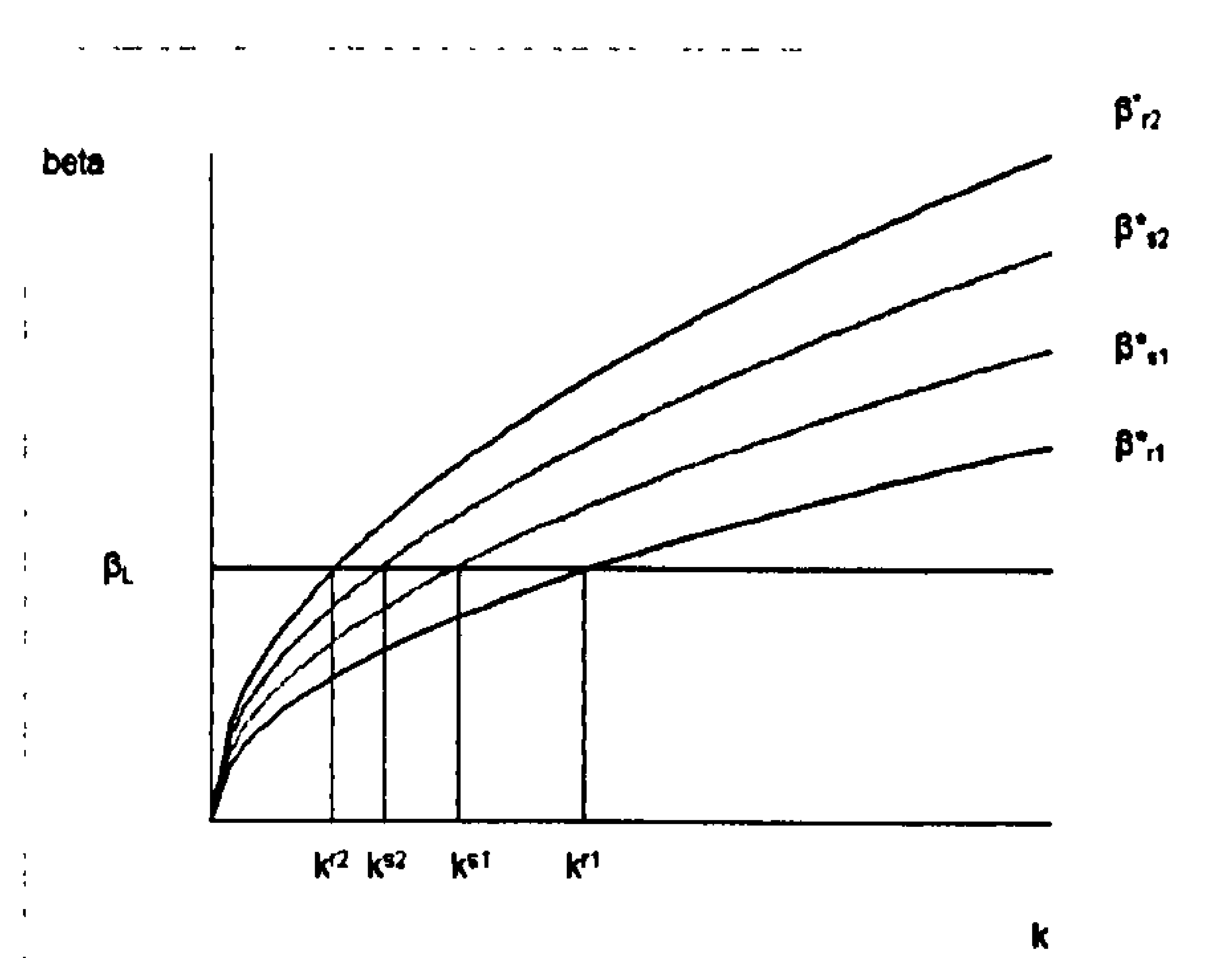



Figure 8: $\beta^*$ functions

Case 1: Dynamic paths $s_2$ and $r$

1.1: $\beta_L > \beta^*_{r_2}$ the lenders offer the pair $(C_H, C_L^r)$.

1.2: $\beta_L < \beta^*_{s_2}$ the lenders offer the pair $\left(C_H, C_l^{s_2}\right)$.

1.3: $\beta^*_{r_2} > \beta_L > \beta^*_{s_2}$ there is no pure strategy equilibrium. Lenders randomize between $(C_H, C_L^r)$ and $\left(C_H, C_l^{s_2}\right)$.

Case 2: Dynamic paths $s_1$ and $r$

2.1: $\beta_L > \beta^*_{s_1}$ the lenders offer the pair$(C_H, C_L^r)$.

2.2: $\beta_L < \beta^*_{r_1}$ the lenders offer the pair$\left(C_H, C_l^{s_1}\right)$.

2.3: $\beta^*_{r_1} > \beta_L > \beta^*_{s_1}$ there is no pure strategy equilibrium. The lenders will randomize between the pairs $(C_H, C_L^r)$ and $\left(C_H, C_l^{s_1}\right)$.

*Proof* See Proof 15

The final step is to define the levels of capital at which switching from each screening path to the rationing path occurs. In other words, we need to calculate the capital stock levels which correspond to the intersection points of the $\beta^*$ functions and $\beta_L$ in Figure 8. We define $k^{r_1}$,$k^{s_1}$, $k^{r_2}$ and $k^{s_2}$ as the levels of capital stock that solve the equations $\beta^*_{r_1} = \beta_L$, $\beta^*_{s_1} = \beta_L$, $\beta^*_{r_2} = \beta_L$ and $\beta^*_{s_2} = \beta_L$ respectively. If we re-arrange $(2.33a - d)$, we obtain the threshold levels of capital:

$$
\begin{aligned}
k^{r_1} &= \beta_L^{\frac{1}{\theta^2}} \left( \frac{\delta^{s_1} (p_L - (1+c)\varepsilon)(p_L - \varepsilon)}{c(p_L - \delta^{s_1}\varepsilon) + \delta^{s_1}(p_L - \varepsilon)} Q (1-\theta)\,\theta A^{\theta - 1} \right)^{-\frac{1}{\theta^2}} && (2.34) \\
k^{s_1} &= \beta_L^{\frac{1}{\theta^2}} \left( \frac{\delta^{s_1} (p_L - (1+c)\varepsilon)(p_L - \varepsilon)}{c(p_L - \delta^{s_1}\varepsilon) + \delta^{s_1}(p_L - \varepsilon)} Q (1-\theta)\,\theta D^{\theta - 1} \right)^{-\frac{1}{\theta^2}} && (2.35) \\
k^{r_2} &= \beta_L^{\frac{1}{\theta^2}} \left( \left( \frac{1}{(1+c)} + \frac{\varepsilon}{p_H} - \frac{\varepsilon}{p_L} - 1 \right) \frac{p_L p_H (p_L - \varepsilon)}{\varepsilon (p_L - p_H)} Q (1-\theta)\,\theta A^{\theta - 1} \right)^{-\frac{1}{\theta^2}} && (2.36) \\
k^{s_2} &= \beta_L^{\frac{1}{\theta^2}} \left( \left( \frac{1}{(1+c)} + \frac{\varepsilon}{p_H} - \frac{\varepsilon}{p_L} - 1 \right) \frac{p_L p_H (p_L - \varepsilon)}{\varepsilon (p_L - p_H)} Q (1-\theta)\,\theta F^{\theta - 1} \right)^{-\frac{1}{\theta^2}} && (2.37)
\end{aligned}
$$

These four levels of capital stock are depicted in Figure 9. Given $\beta^*_{r_1} < \beta^*_{s_1} < \beta^*_{s_2} < \beta^*_{r_2}$, we obtain that $k^{r_2} < k^{s_2} < k^{s_1} < k^{r_1}$.

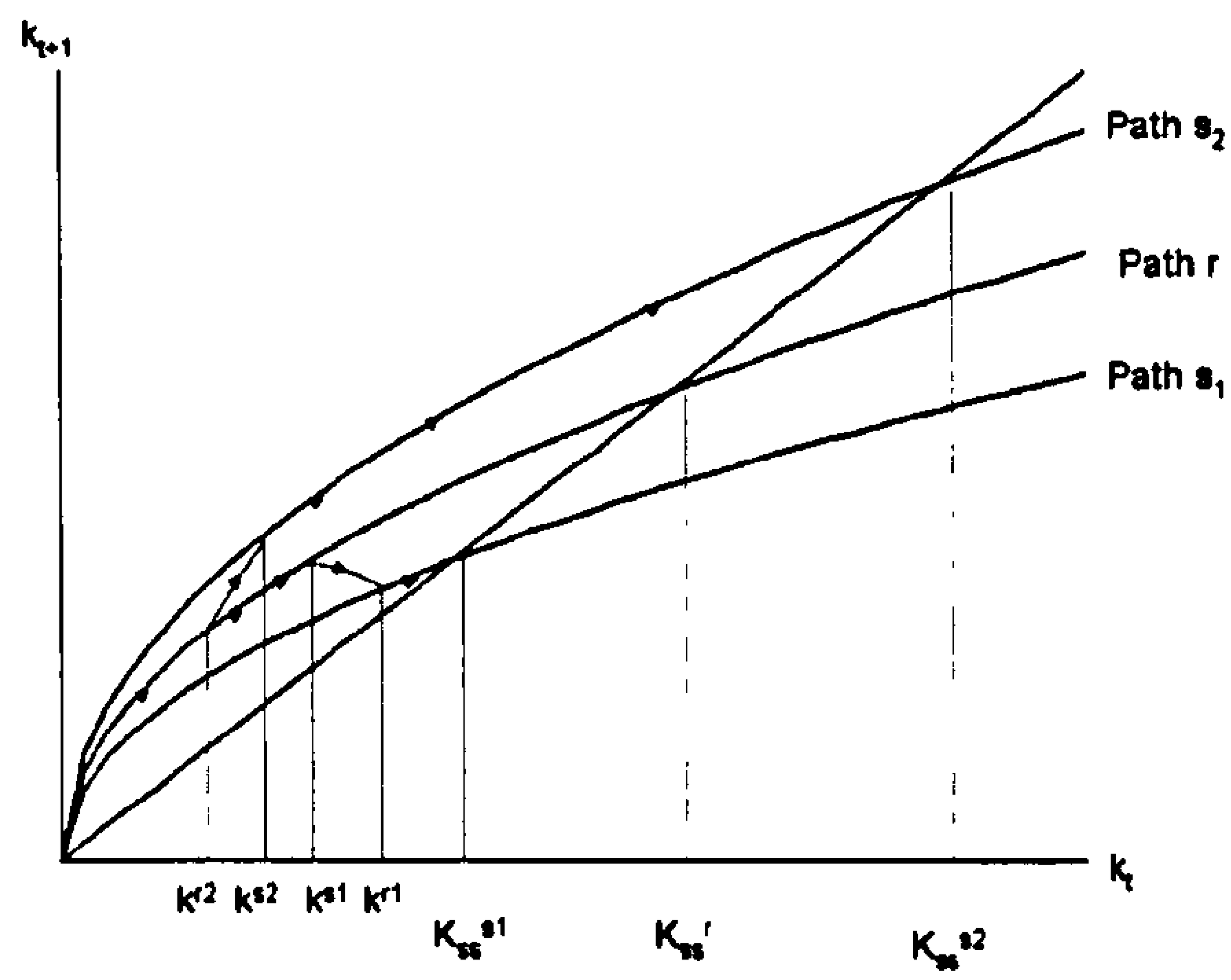



Figure 9

The following Proposition summarizes the above results about the prevailing regime in a developed economy by combining the findings about the relationship between the four different values of $\beta^*$ to $\beta_L$ and the respective threshold levels of the capital stock:

**Proposition 2.8** *Case 1: Dynamic paths $s_2$ and $r$*

*1.1:* $\beta_L > \beta^*_{r_2}$, *or equivalently* $k_t < k^{r_2}$, *rationing prevails and lenders offer* $(C_H, C_L^r)$

*1.2:* $\beta^*_{r_2} > \beta_L > \beta^*_{s_2}$, *or equivalently* $k^{r_2} < k_t < k^{s_2}$, *there is a mixed equilibrium where lenders offer* $(C_H, C_L^r)$ *and* $\left(C_H, C_l^{s_2}\right)$.

*1.3:* $\beta_L < \beta^*_{s_2}$, *or equivalently* $k^{s_2} < k_t$, *screening prevails and lenders offer* $\left(C_H, C_l^{s_2}\right)$

*Case 2: Dynamic paths $s_1$ and $r$*

*2.1:* $\beta_L > \beta^*_{s_1}$, *or equivalently* $k_t < k^{s_1}$, *rationing prevails and lenders offer* $(C_H, C_L^r)$.

*2.2:* $\beta^*_{s_1} > \beta_L > \beta^*_{r_1}$, *or equivalently* $k^{s_1} < k_t < k^{r_1}$, *there is a mixed equilibrium where lenders offer* $(C_H, C_L^r)$ *and* $\left(C_H, C_l^{s_1}\right)$.

*2.3: $\beta_L < \beta^*_{r_1}$, or equivalently $k^{r_1} < k_t$, screening prevails and lenders offer $(C_H, C_l^{s_1})$.*

We now discuss the findings and explain the implications for the general equilibrium of the economy. The first and most obvious point is that the pair of contracts $(C_H, C_l^{s_2})$ leads to the highest dynamic path and thus convergence to Path $s_2$ is best for the economy.

Inspection of the expressions which define the steady state levels of capital ((2.23), (2.27), (2.29)) and the levels of capital at which lenders switch between regimes ($2.33a, b$) show that it is not possible to rank them. Thus we will look at them case by case.

If we assume that the initial capital stock is less than all threshold and steady state capital levels, then initially the contracting regime is the rationing one and the economy grows along Path $r$.

When $k^{r_2} < k^{s_2} < k^r_{ss} < k^{s_2}_{ss}$ ( $k^{s_1} < k^{r_1} < k^{s_1}_{ss} < k^r_{ss}$) the contracting regime changes to a mix of rationing and screening at the level of capital $k^{r_2}$ ($k^{s_1}$). The capital accumulation path lies between Path $r$ and Path $s_1$ ($s_2$) and the economy grows along the path joining $k^{r_2}$ and $k^{s_2}$ ( $k^{r_1}$ and $k^{s_1}$). However, once the capital stock reaches $k^{s_2}$ ($k^{r_1}$), the equilibrium regime is screening and capital accumulates along Path $s_1$ ($s_2$). The economy converges to the screening steady state $k^{s_2}_{ss}$ ($k^{s_1}_{ss}$). The convergence from Path $r$ to Path $s_2$ is a typical upward movement to a higher dynamic path and higher steady state level of capital. However, the switch from Path $r$ to Path $s_1$ is more peculiar in the sense that Path $s_1$ is lower than the rationing Path $r$ and thus leads the economy to a relatively low steady state for the capital stock. So, if the policy makers cannot enforce the use of $\delta^{s_2}$ over $\delta^{s_1}$ (e.g. by setting regulations and laws about the quality of the screening technology used by the lenders), the economy runs the risk of converging to the lowest steady state as the economy switches from the rationing to the screening regime. This situation is depicted in Figure 9.

However, when $k^r_{ss} < k^{r_2} < k^{s_2} < k^{s_2}_{ss}$ the economy converges to the low steady state $k^r_{ss}$ before it gets to a point where switching to the screening regime would occur and hence the switch never happens. In other words, if the threshold level of capital at which the economy changes from rationing to screening is relatively high then the rationing regime prevails at all times. This case is depicted in Figure 10. Obviously, the same holds for $k^r_{ss} < k^{s_2}_{ss} < k^{r_2} < k^{s_2}$.

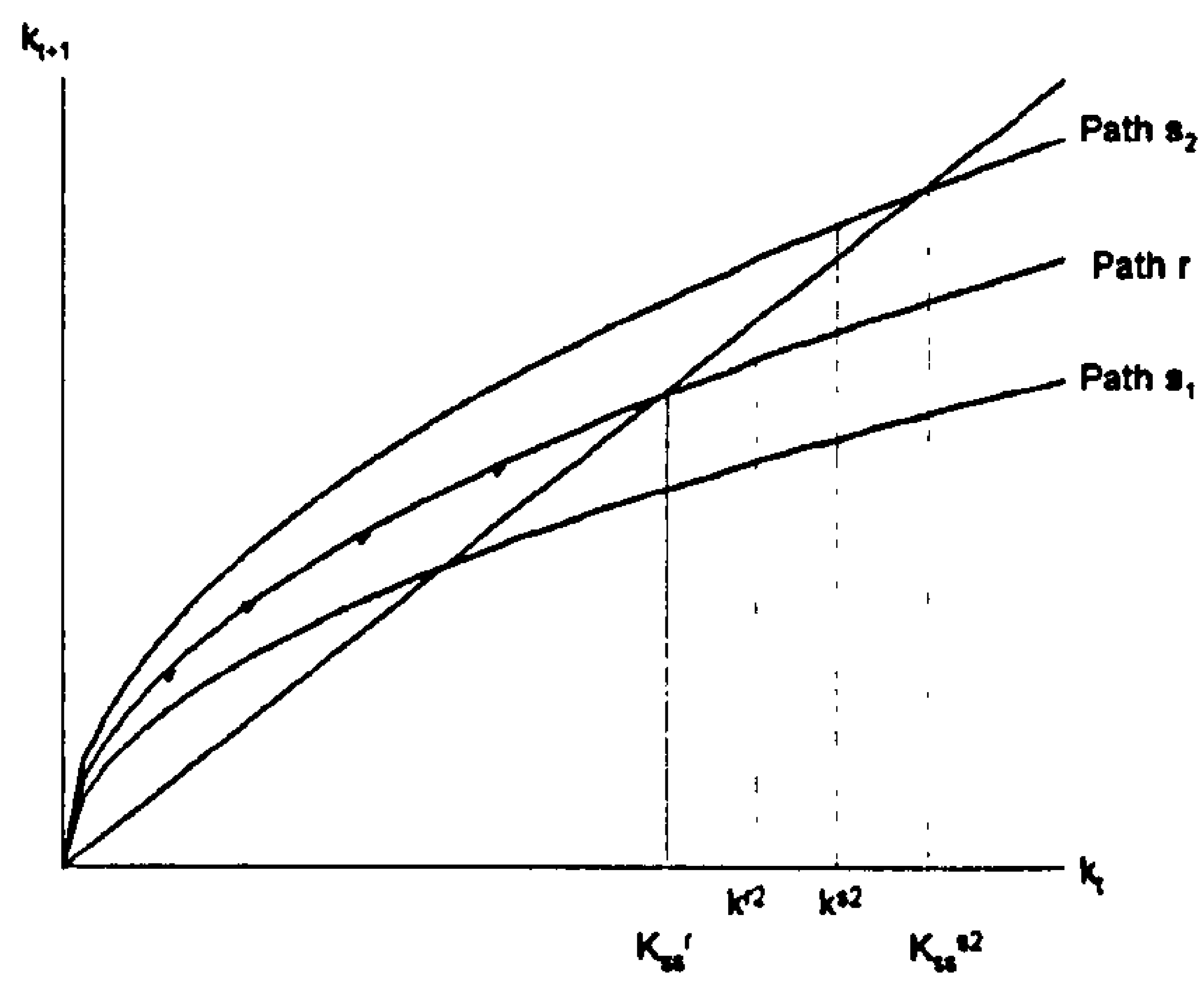



Figure 10

There is a peculiar situation, that of $k^{s_1}_{ss} < k^{s_1} < k^r < k^r_{ss}$ where there will be no steady state equilibrium in the economy. The economy will experience periods of high and low capital stocks and growth.[13] Moreover, a mix of rationing and screening will always prevail. To see this remember that for any level of capital lower than $k^{r_1}$, capital accumulates along Path $r$. In the interval $[k^{s_1}, k^{r_1}]$ the capital accumulation path lies between Path $r$ to Path $s_1$. When capital accumulates further and exceeds $k^{r_1}$ it will tend to start accumulating along Path $s_1$. However, since the steady state level of capital $k^{s_1}_{ss}$ is smaller than $k^{r_1}$ there will be movement to the left. The decrease of capital will terminate when capital reaches the level $k^{s_1}$. Then, the above cyclical effect continues. This situation is depicted in Figure 11.

[13] Such a cyclical equilibria situation is not new in the literature of growth, see e.g. Aghion and Howitt (1992).

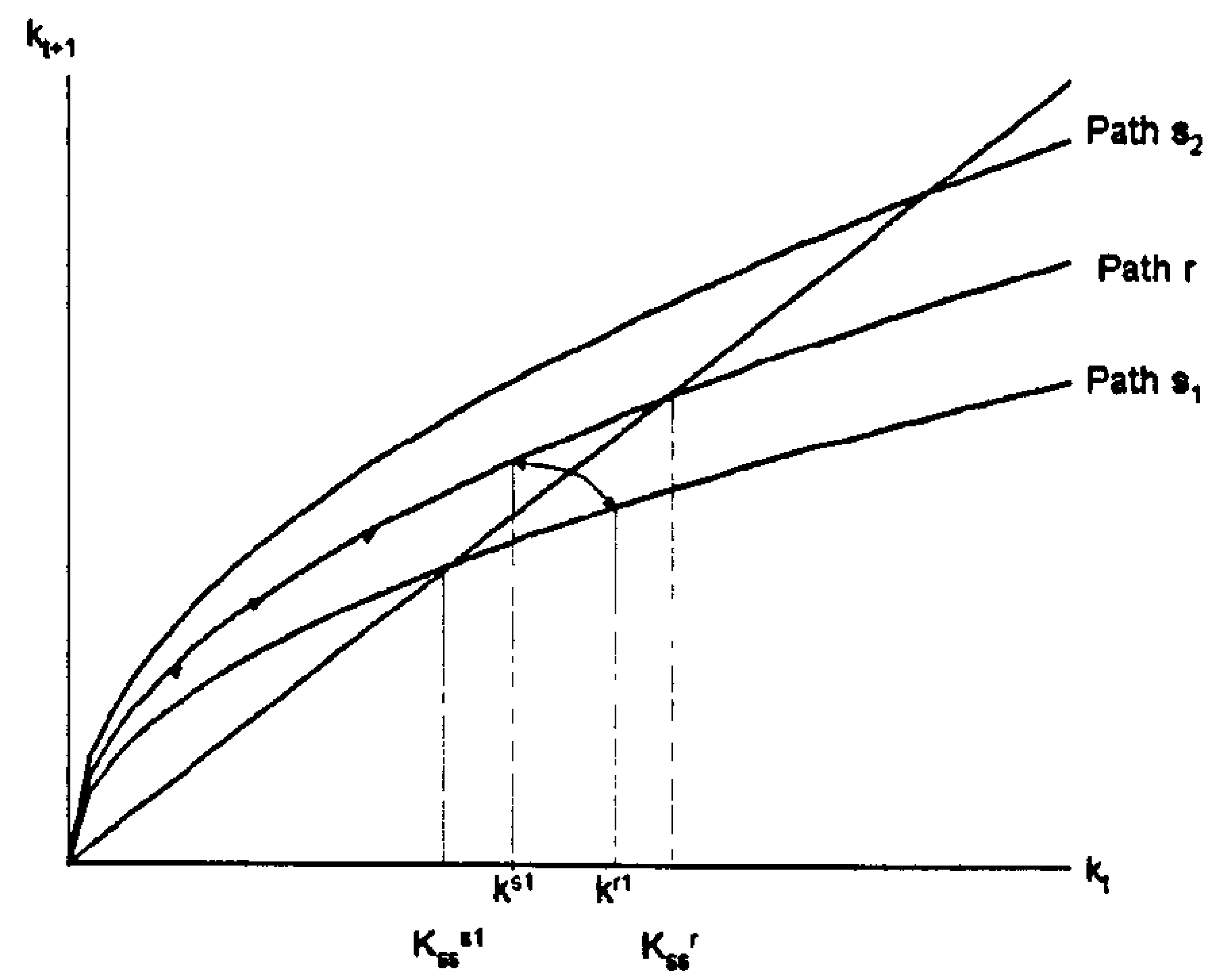



Figure 11

Finally, when $k_{ss}^{s_1} < k_{ss}^{r} < k^{s_1} < k^{r}$, the economy converges to the rationing steady state $k_{ss}^{r}$.

### 2.6.2 Path $s_1 >$ Path $r$

The production function exhibits diminishing returns to capital and thus $\rho_{t+1}^{r} > \rho_{t+1}^{s_1} > \rho_{t+1}^{s_2}$. Since $\beta_{r_1}^{*}$, $\beta_{s_1}^{*}$, $\beta_{r_2}^{*}$ and $\beta_{s_2}^{*}$ are increasing functions of $k_t$ and $(\theta - 1) < 0$ we obtain that now $\beta_{r_1}^{*} > \beta_{s_1}^{*}$ as $A < D$ and $\beta_{r_2}^{*} > \beta_{s_2}^{*}$ as $A < F$. Moreover, $\beta_{s_1} < \beta_{s_2}$ (see *Proof 14*). Thus, the ranking of the $\beta^{*}$ functions becomes $\beta_{s_1}^{*} < \beta_{r_1}^{*} < \beta_{s_2}^{*} < \beta_{r_2}^{*}$ and thus $k^{r_2} < k^{s_2} < k^{r_1} < k^{s_1}$. In Figure 12 we plot the $\beta^{*}$ functions of $(2.33a - d)$ and an arbitrary $\beta_L$. The analysis is similar to the previous section. Depending on how the $\beta^{*}$ functions compare to $\beta_L$ there is a different equilibrium pair of contracts:

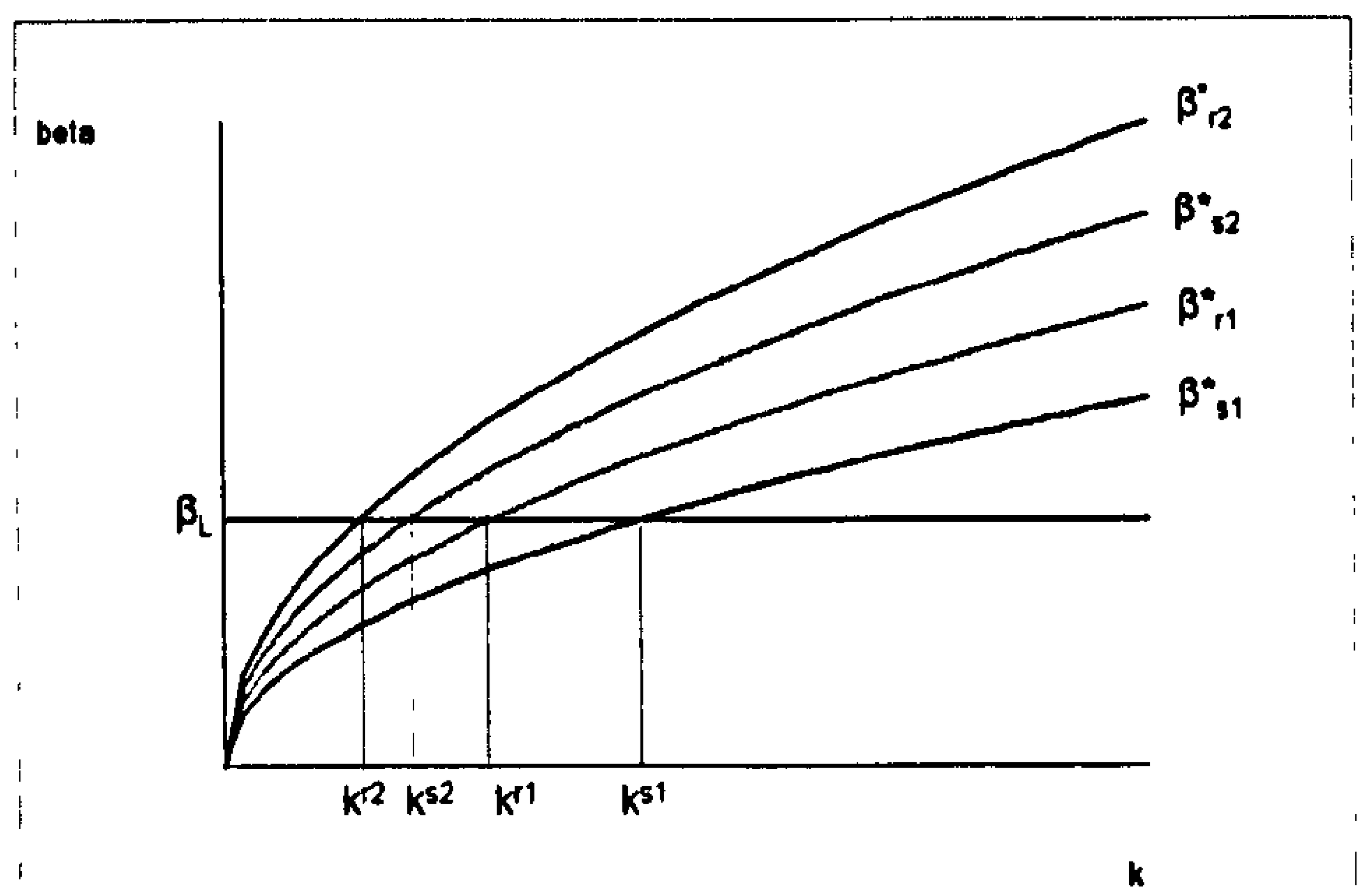



Figure 12

Case 1: Dynamic paths $s_2$ and $r$

1.1: $\beta_L > \beta^*_{r_2}$ the rationing contract pair $(C_H, C^r_L)$ is the only equilibrium pair at time $t$.

1.2: $\beta_L < \beta^*_{s_2}$ the lenders offer the pair $\left(C_H, C^{s_2}_l\right)$.

1.3: $\beta^*_{r_2} > \beta_L > \beta^*_{s_2}$ there is no pure strategy equilibrium. Lenders randomize between $(C_H, C^r_L)$ and $\left(C_H, C^{s_2}_l\right)$.

Case 2: Dynamic paths $s_1$ and $r$

2.1: $\beta_L > \beta^*_{r_1}$the rationing contract pair $(C_H, C^r_L)$ is the only equilibrium pair at time $t$.

2.3: $\beta_L < \beta^*_{s_1}$the lenders offer the pair $\left(C_H, C^{s_1}_l\right)$. .

2.2: $\beta^*_{r_1} > \beta_L > \beta^*_{s_1}$ there is no pure strategy equilibrium. Lenders randomize between $(C_H, C^r_L)$ and $\left(C_H, C^{s_1}_l\right)$.

*Proof* See Proof 15

Given $\beta^*_{s_1} < \beta^*_{r_1} < \beta^*_{s_2} < \beta^*_{r_2}$, we now obtain that $k^{r_2} < k^{s_2} < k^{r_1} < k^{s_1}$. Figure 13 depicts these switching levels of capital and Proposition 2.11 summarizes the above results about the prevailing regime in a developed economy when Path $s_1$ is higher than Path $r$.

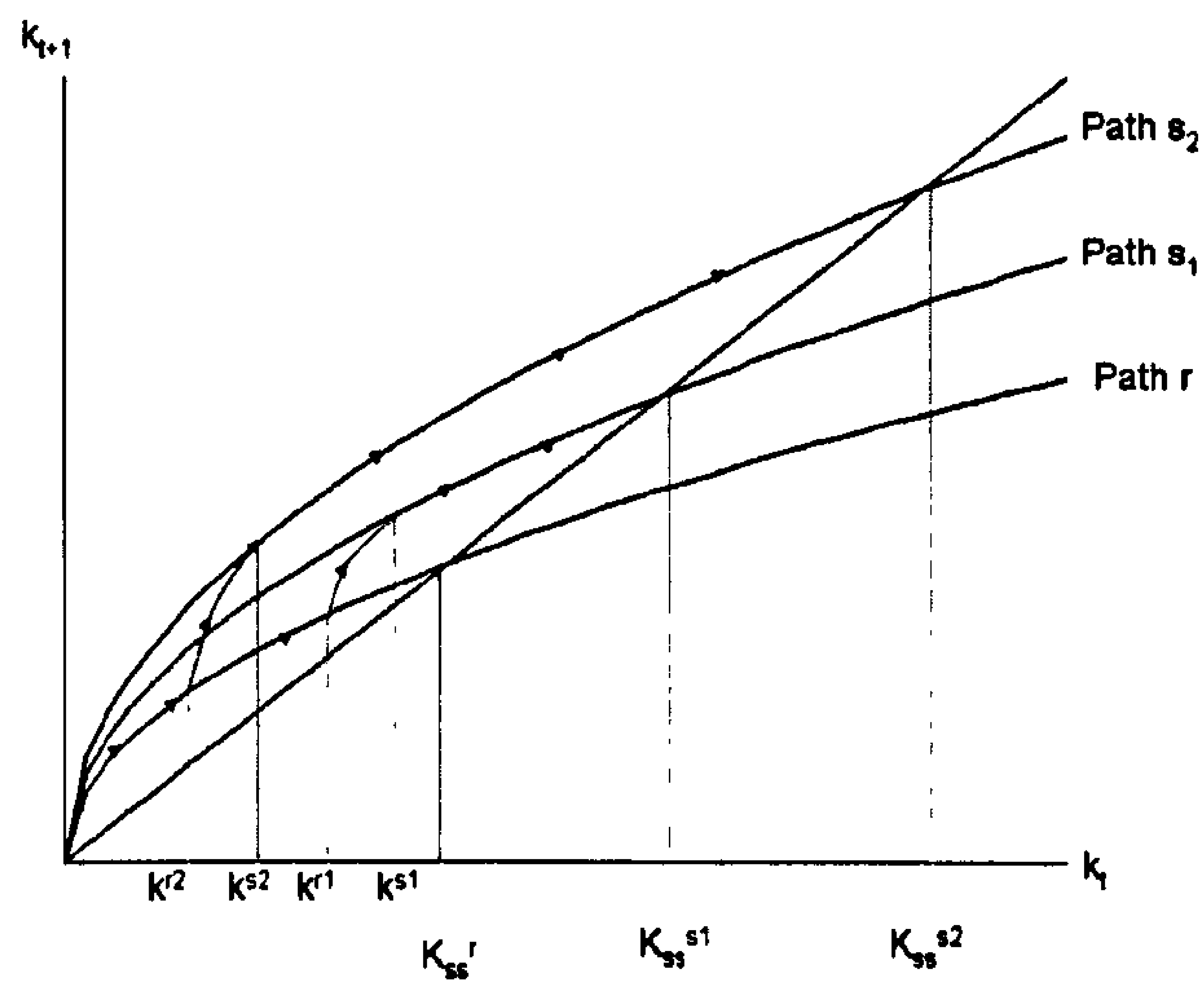



Figure 13

**Proposition 2.9** *Case 1: Dynamic paths* $s_2$ *and* $r$

*1.1:* $\beta_L > \beta^*_{r_2}$, *or equivalently* $k_t < k^{r_2}$, *rationing prevails and lenders offer* $(C_H, C_L^r)$

*1.2:* $\beta^*_{r_2} > \beta_L > \beta^*_{s_2}$, *or equivalently* $k^{r_2} < k_t < k^{s_2}$, *there is a mixed equilibrium where lenders offer* $(C_H, C_L^r)$ *and* $\left(C_H, C_l^{s_2}\right)$.

*1.3:* $\beta_L < \beta^*_{s_2}$, *or equivalently* $k^{s_2} < k_t$, *screening prevails and lenders offer* $\left(C_H, C_l^{s_2}\right)$

*Case 2: Dynamic paths* $s_1$ *and* $r$

*2.1:* $\beta_L > \beta^*_{r_1}$, *or equivalently* $k_t < k^{r_1}$, *rationing prevails and lenders offer* $(C_H, C_L^r)$.

*2.2:* $\beta^*_{r_1} > \beta_L > \beta^*_{s_1}$, *or equivalently* $k^{r_1} < k_t < k^{s_1}$, *there is a mixed equilibrium where lenders offer* $(C_H, C_L^r)$ *and* $\left(C_H, C_l^{s_1}\right)$.

*2.3:* $\beta_L < \beta^*_{s_1}$, *or equivalently* $k^{s_1} < k_t$, *screening prevails and lenders offer* $\left(C_H, C_l^{s_1}\right)$.

Similarly to the previous case, the pair of contracts $\left(C_H, C_l^{s_2}\right)$ leads to the highest dynamic path and convergence to Path $s_2$ is best for the economy. Both screening paths lie above the rationing path and thus the screening contract is always preferred for the economy. We now look at the possible rankings of the steady state levels of capital ((2.23), (2.27), (2.29)) and the levels of capital at which lenders switch between regimes $(2.33a - d)$.

If we assume that the initial capital stock is less than all threshold and steady state capital levels, then initially the contracting regime is the rationing one and economy grows along Path $r$.

When $k^{r_2} < k^{s_2} < k^r_{ss}$ ( $k^{r_1} < k^{s_1} < k^r_{ss}$) the contracting regime changes to a mix of rationing and screening at the level of capital $k^{r_2}$ ($k^{r_1}$). The capital accumulation path lies between Path $r$ and $s_2$ ($s_1$) and the economy grows along the path joining $k^{r_2}$ and $k^{s_2}$ ( $k^{r_1}$ and $k^{s_1}$). However, once the capital stock reaches $k^{s_2}$ ($k^{s_1}$), the equilibrium regime is screening and capital accumulates along Path $s_2$ ($s_1$). The economy converges to the higher steady state level of capital $k^{s_2}_{ss}$ ($k^{s_1}_{ss}$). This situation is depicted in Figure 12.

However, if $k^r_{ss} < k^{r_2} < k^{s_2} < k^{s_2}_{ss}$ ( $k^r_{ss} < k^{r_1} < k^{s_1} < k^{s_1}_{ss}$) the economy converges to the low steady state $k^r_{ss}$ before it gets to a point where switching to the screening regime could occur. In other words, if the level of capital at which the economy switches from the rationing to the screening regime is relatively high, then the rationing regime prevails at all times. This case is depicted by Figure 14. Obviously, the same holds for the case $k^r_{ss} < k^{s_2}_{ss} < k^{r_2} < k^{s_2}$ ( $k^r_{ss} < k^{s_1}_{ss} < k^{r_1} < k^{s_1}$).

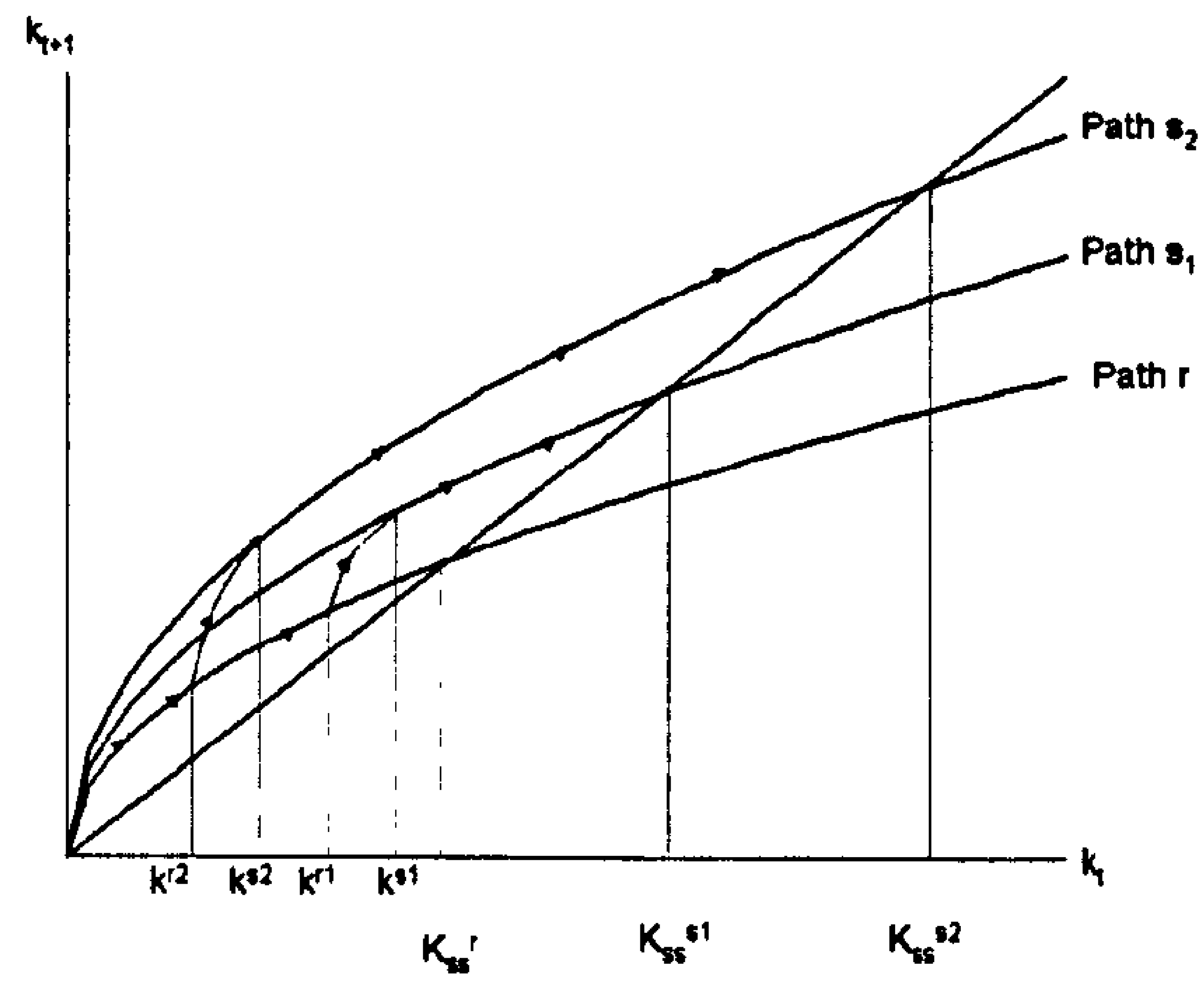



Figure 14

Notice that the capital dynamics described in this section are similar to the ones found by BC with the two paths being the rationing Path $r$ and one of Path $s_1$ or Path $s_2$ describing the perfect screening path.

Summarizing the findings up to now we see that the lending regime is endogenously determined. So, although first, the expected payoff of the borrowers defines whether the screening or the rationing regime prevails and second, the exogenous choice of $\delta^{s_1}$ or $\delta^{s_2}$ defines which screening contract is going to be offered by the lenders, it is the economic environment (or the relative positioning of the rationing and screening capital dynamic paths) which defines the steady state equilibrium. So, when both Path $s_1$ and Path $s_2$ lie above Path $r$, the screening regime leads to a higher dynamic path and a higher steady state of capital compared to the rationing regime, similar to the predictions of BC. However, our model shows that the framework of BC describes just one of the cases that can be observed in an economy where screening is available as a means of separating borrowers by type. Once we introduce a more realistic assumption about the screening technology, that of imperfect screening methods, more scenarios emerge as potential general equilibrium states. The screening regime is often but not always the best method of separating borrowers nor is it a panacea for developed and undeveloped economies. More specifically, when Path $s_1$ lies below Path $r$, switching from the rationing regime to screening might imply convergence to a lower dynamic path and steady state for capital. Moreover, the relative positioning of the threshold levels of capital and the steady state levels of capital is crucial in defining the steady state of the economy. This impact varies both across the different pairs of contracts $(C_H, C_l^{s_1})$ and $(C_H, C_l^{s_2})$ as well as across the relative position of the capital accumulation paths.

## 2.7 More on capital dynamics

From the point of view of policy makers it is of interest to know how a change in a policy instrument will affect the steady state of the economy at each situation. The policy instruments of our model are the quality of screening and the level of the screening cost. In BC a decrease in the cost of screening is seen as an increase in the degree of financial sophistication. However, in our model such an improvement can be reflected in the same implicit way i.e. a decrease in the cost of screening or, explicitly, by an increase of the quality of screening. A policy that would facilitate the implicit increase in the degree of financial sophistication is a decrease to the cost of screening through direct subsidization of the screening cost. As for an explicit increase in the degree of financial sophistication, policy makers can set regulations and laws about the quality of the screening technology used by the lenders e.g. set sound accounting auditing and disclosure regulations. Moreover, giving incentives to institutions that provide information about borrowers can indirectly improve the informational infrastructure in the financial sector. For example, our model shows that an economy would reach a higher steady state of capital if lenders choose $\delta^{s_2}$ over $\delta^{s_1}$ i.e. if they offer $C_l^{s_2}$ instead or $C_l^{s_1}$, but similar reasoning can be used to asses the importance of higher values of the exogenous $\delta^{s_1}$ or $\delta^{s_2}$ given the choice of $C_l^{s_2}$ or $C_l^{s_1}$. However, there are some special cases which we now consider in detail.

Case 1: $(C_H, C_L^r)$ and $(C_H, C_l^{s_2})$

In Section 5 we saw that an increase in the quality of screening or a decrease in the screening cost shifts the capital dynamic Path $s_2$ up. However, it is possible that an economy can still get trapped in the lower steady state $k_{ss}^r$. More specifically, when $k_{ss}^r < k^{r_2} < k^{s_2} < k_{ss}^{s_2}$ we have seen that the economy converges to the low steady state of capital $k_{ss}^r$ before getting to the point where switching to the screening regime would occur. In that case a change of $c$ or $\delta^{s_2}$ will have no effect on the economy. However, the economy can avoid getting trapped at the low steady state by adopting a policy which will force the switching level of capital $k^{r_2}$ to "shift" to the left of $k_{ss}^r$. Remember that $k_{ss}^r$ is independent of both $c$ and $\delta^{s_2}$ but $k^{r_2}$ is an increasing function of $c$ and a decreasing function of $\delta^{s_2}$ (see Proof 16). Thus, a decrease of $c$ or an increase of $\delta^{s_2}$ will allow the economy to get to the point where switching to the higher Path $s_2$ would occur before converging to the low steady state $k_{ss}^r$. In other words, there is a threshold cost of information which needs to be reached before $c$ can affect the economy's growth path and steady state, similarly to BC. Such a result is naturally extended in our model and also holds for the quality of screening.

Case 2: $(C_H, C_L^r)$ and $(C_H, C_l^{s_1})$

As we showed in Section 5, an increase in the quality of screening shifts the capital dynamic Path $s_1$ up but a decrease in the cost of screening might shift Path $s_1$ up or down due to the trade-off between the resources spent and the probability of a borrower getting a loan and thus running the project. Regardless of an upward or downward shift, there are cases where a threshold level of $c$ or $\delta^{s_1}$ is needed before a policy change can affect an economy's growth path and steady state. When Path $s_1$ lies above Path $r$, a country might get trapped in a low level of development when $k_{ss}^r < k^{r_1} < k^{s_1} < k_{ss}^{s_1}$. Since $k_{ss}^r$ is independent of both $c$ and $\delta^{s_1}$ but $\frac{\partial k^{r_1}}{\partial c} > 0$ and $\frac{\partial k^{r_1}}{\partial \delta^{s_1}} < 0$ (see Proof 17), $c$ needs to fall below or $\delta^{s_1}$ need to increase above a threshold level before any change in the policy instruments can affect the economy's growth path and steady state.

However, when Path $s_1$ lies below Path $r$, a country might get trapped in a situation where the economy experiences alternating periods of high and low capital stocks and growth if $k^{s_1}_{ss} < k^{s_1} < k^{r_1} < k^{r}_{ss}$. In this case, the investigation of the effects is more complicated than before since both $k^{s_1}_{ss}$ and $k^{s_1}$ depend on $c$ and $\delta^{s_1}$. In Proof 8 we show that $\frac{\partial D}{\partial c} \lesseqgtr 0$ and $\frac{\partial D}{\partial \delta^{s_1}} > 0$. Since $k^{s_1}_{ss} = D^{1/(1-\theta)}$ it follows that $\frac{\partial k^{s_1}_{ss}}{\partial c} \lesseqgtr 0$ and $\frac{\partial k^{s_1}_{ss}}{\partial \delta^{s_1}} > 0$. Moreover, in Proof 18 we show that $\frac{\partial k^{s_1}}{\partial c} > 0$ but also $\frac{\partial k^{s_1}}{\partial \delta^{s_1}} \lesseqgtr 0$.[14] Thus, it is obvious that we cannot generalize on the impact of a change in a policy instrument as it is the relative change of $k^{s_1}_{ss}$ and $k^{s_1}$ which will define the outcome.

## 2.8 Conclusion

It has long been suggested that modeling informational imperfections is crucial for a better understanding of financial markets' impact on economic growth. This paper models the loan markets in a more realistic manner in the sense that the technology used to obtain information about potential borrowers is allowed to be imperfect.

We show that although credit rationing can be used by any country as a mechanism of separating borrowers, this does not hold true for screening, contrary to earlier findings. More specifically, we find that in undeveloped countries rationing is the only equilibrium way of separating borrowers and the screening cost needs to decrease, or the difference in the rates of return between the home technology and an investment project to increase above a threshold, for the screening contract to become relevant. In developed economies, lenders can separate borrowers by denying credit to a fraction of them at low levels of capital accumulation whereas they start using a screening technology to obtain information about potential borrowers as capital accumulates. Such a transition from rationing to screening may imply a lower or higher dynamic path and steady state for the capital stock. The economic environment can change the equilibrium contract terms within each regime but can

[14] The last result is counter intuitive since we would expect the quality of screening to have a negative relation with the threshold level.

also change the equilibrium regime itself. Moreover, we find that a screening regime does not always dominate a rationing regime in the sense of delivering higher dynamic capital paths and steady state level for capital, contrary to preexisting models.

Finally, our model verifies earlier findings about the "threshold effect" of the screening cost and predicts that the quality of screening should also be above a threshold level before it can affect an economy's growth path and the steady-state of capital.

An interesting extension of our model would be to endogenise the screening cost. This can be done by a two stage game solved by backward induction where the lenders choose to use the quality of screening which maximizes their expected payoff, given the contract terms which maximize the expected payoff of the borrowers. Another direction would be to allow the screening cost to depend on the quality of screening and allow learning to have a beneficial effect on the quality of the screening or its cost. Obviously, another natural extension of our work would be to allow for imperfections in the screening process of both types of borrowers.

## 2.9 Appendix

**Proof. 1: Derivation of $C_L^T$**

Given $C_H = (R_{Ht}, q_{Ht}, \pi_{Ht}) = \left(\frac{Q\varepsilon\rho_{t+1}}{p_H}, w_t, 1\right)$, the lender finds the optimal $C_L^T$ by maximizing the following program: Select $(\pi_{Lt}, q_{Lt})$ to

$$\text{Maximize } EP_L\left(C_L^T\right) = \pi_{Lt} p_L \left(Q\rho_{t+1} - R_{Lt}\right) q_{Lt} + (1 - \pi_{Lt}) \beta_L \tag{2.38}$$

subject to

$$\pi_{Lt} q_{Lt} \left(p_L R_L - Q\varepsilon\rho_{t+1}\right) = 0$$

$$q_{Lt} \leq w_t$$

$$0 \leq \pi_{Lt} \leq 1$$

$$\pi_{Ht} p_H \left(Q\rho_{t+1} - R_{Ht}\right) q_{Ht} \geq \pi_{Lt} p_H \left(Q\rho_{t+1} - R_{Lt}\right) q_{Lt} \tag{2.39}$$

or, if we substitute the equilibrium values $\pi_{Ht} = 1$, $q_{Ht} = w_t$ and $R_{Ht} = \frac{Q\varepsilon\rho_{t+1}}{p_H}$ into the incentive compatibility constraint of the high-risk borrower (2.39) and take it as equality, it becomes:

$$q_{Lt} = \frac{(1 - \varepsilon/p_H)\, w_t}{(1 - \varepsilon/p_L)\, \pi_{Lt}} \tag{2.40}$$

However, the above maximization can be simplified. The feasibility constraint $q_{Lt} \leq w_t$ implies that (2.40) should satisfy:

$$\pi_{Lt} \geq \frac{1 - \varepsilon/p_H}{1 - \varepsilon/p_L} \tag{2.41}$$

If we substitute (2.40) in the objective function (2.38) and maximize it with respect to $\pi_{Lt}$ we see that, given $C_H$, $q_{Lt}$ and $R_{Lt}$, the expected payoff for the low-risk borrower is strictly decreasing to $\pi_{Lt}$ since

$$\frac{\partial EP_L\left(C_L^T\right)}{\partial \pi_{Lt}} = -\beta_L < 0$$

Thus, the lender will offer the smallest $\pi_{Lt}$ i.e. $\pi_{Lt} = \frac{1-\varepsilon/p_H}{1-\varepsilon/p_L}$. So, finally the equilibrium contract terms for $C_L^r$ are:

$$C_L^r = (R_{Lt}^r, q_{Lt}^r, \pi_{Lt}^r) = \left( \frac{Q\varepsilon\rho_{t+1}}{p_L}, w_t, \frac{1-\varepsilon/p_H}{1-\varepsilon/p_L} \right)$$

### Participation Constraints

During the maximization procedure it has been assumed that the participation constraints for the low and high risk borrowers are not binding. We need to verify that this assumption is true for the equilibrium contract terms. The participation constraints for the low risk borrowers is given by (2.12) and is rewritten below for convenience:

$$\pi_{Lt} p_L \left( Q\rho_{t+1} - R_{Lt} \right) q_{Lt} + (1 - \pi_{Lt}) \beta_L \geq \beta_L \tag{2.42}$$

For $\pi_{Lt} = \frac{1-\varepsilon/p_H}{1-\varepsilon/p_L}$, (2.8) implies that it is not binding. Similarly, the participation constraints for the high risk borrowers is given by (2.13) and is rewritten below for convenience:

$$\pi_{Ht} p_H \left( Q\rho_{t+1} - R_{Ht} \right) q_{Ht} \geq 0$$

For $\pi_{Ht} = 1$, (2.8) implies that it is not binding (remember we have assumed that $\beta_H = 0$).

For future reference we would like to define the point at which a low risk borrower is indifferent between the rationing contract and his home technology. Thus, substituting the equilibrium contract terms of $C_L^r$ in the participation constraint of the low risk borrower, we define:

$$\beta^r = Q\rho_{t+1} (p_L - \varepsilon) w_t > \beta_L \tag{2.43}$$

■

**Proof. 2: The $IC_H$ constraint binds and the $IC_L$ constraint does not bind**

**Case 1: The $IC_H$ constraint binds and the $IC_L$ constraint does not bind**

If we substitute the equilibrium values $q_{Ht} = w_t$, $\pi_{Ht} = 1$, $R_{Ht} = \frac{Q\varepsilon\rho_{t+1}}{p_H}$, $\pi_{Lt} = \frac{1-\varepsilon/p_H}{1-\varepsilon/p_L}$, $q_{Lt} = w_t$ and $R_{Lt} = \frac{Q\varepsilon\rho_{t+1}}{p_L}$ in the left hand side of the $IC_H$ given by (2.39) we obtain:

$Q\rho_{t+1}w_t\left(p_H - \varepsilon\right)$

But from the right hand side of (2.39) we obtain

$Q\rho_{t+1}w_t\left(p_H - \varepsilon\right)$

Thus, the incentive compatibility constraint for the $H$ type borrower indeed holds with equality in the equilibrium.

Similarly, if we substitute above equilibrium values in the left hand side of $IC_L$ given by (2.14):

$\left(Q\rho_{t+1} - \frac{Q\varepsilon\rho_{t+1}}{p_H}\right) p_L w_t + \left(1 - \frac{1-\varepsilon/p_H}{1-\varepsilon/p_L}\right)\beta_L > p_L\left(Q\rho_{t+1} - \frac{Q\varepsilon\rho_{t+1}}{p_H}\right) w_t$

Thus, the incentive compatibility constraint for the $L$ type borrower indeed holds with strict inequality in the equilibrium.

**Case 2: The $IC_L$ binds and the $IC_H$ does not bind**

If we assume that the $IC_L$ is binding but the $IC_H$ is not binding then the maximization problem for the $L$ type borrower is:

$$\text{Maximize } EP_L\left(C_L\right) = \pi_{Lt}p_L\left(Q\rho_{t+1} - R_{Lt}\right)q_{Lt} + \left(1 - \pi_{Lt}\right)\beta_L$$

subject to

$$R_{Lt} = \frac{Q\varepsilon\rho_{t+1}}{p_L}$$

$$q_{Lt} \leq w_t$$

$$0 \leq \pi_{Lt} \leq 1$$

So, as long as (2.8) holds, the expected payoff for type $L$ borrowers is strictly increasing at both control variables and thus maximized by the corner solution. Thus, the low-risk borrower is offered his first-best contract $C_L = (R_{Lt}, q_{Lt}, \pi_{Lt}) = \left(\frac{Q\varepsilon\rho_{t+1}}{p_L}, w_t, 1\right)$

The maximization problem for the $H$ type borrower is:

$$\text{Maximize } EP_H\left(C_H^\tau\right) = \pi_{Ht} p_H \left(Q\rho_{t+1} - R_{Ht}\right) q_{Ht} \tag{2.44}$$

subject to

$$\begin{aligned} &\pi_{Lt} p_L \left(Q\rho_{t+1} - R_{Lt}\right) q_{Lt} + (1 - \pi_{Lt}) \beta_L \geq \\ &\pi_{Ht} p_L \left(Q\rho_{t+1} - R_{Ht}\right) q_{Ht} + (1 - \pi_{Ht}) \beta_L \end{aligned} \tag{2.45}$$

$$R_{Ht} = \frac{Q\varepsilon\rho_{t+1}}{p_H}, \; q_{Ht} \leq w_t \text{ and } 0 \leq \pi_{Ht} \leq 1$$

or, if we substitute the equilibrium values $\pi_{Lt} = 1$, $q_{Lt} = w_t$ and $R_{Lt} = \frac{Q\varepsilon\rho_{t+1}}{p_L}$ into the incentive compatibility constraint of the low-risk borrower and take it as inequality, it becomes:

$$q_{Ht} = \frac{p_H \left(Q\rho_{t+1} (p_L - \varepsilon) w_t - (1 - \pi_{Ht}) \beta_L\right)}{Q\rho_{t+1} \pi_{Ht} p_L (p_H - \varepsilon)} \tag{2.46}$$

However, above maximization can be simplified. The feasibility constraint $q_{Ht} \leq w_t$ implies that (2.46) should satisfy:

$$\pi_{Ht} \geq \frac{w_t Q\rho_{t+1} p_H (p_L - \varepsilon) - p_H \beta_L}{w_t Q\rho_{t+1} p_L (p_H - \varepsilon) - p_H \beta_L} \tag{2.47}$$

If we substitute $R_{Ht}$ and (2.46) into the maximand, the problem changes to maximizing:

$$EP_H\left(C_H^\tau\right) = \frac{p_H \left(Q\rho_{t+1} (p_L - \varepsilon) w_t - (1 - \pi_{Ht}) \beta_L\right)}{p_L} \tag{2.48}$$

subject to the restrictions $1 \geq \pi_{Ht}$ and (2.47). Since $\frac{\partial}{\partial \pi_{Ht}} = p_H \beta_L / p_L > 0$, the expected payoff is strictly increasing in $\pi_{Ht}$ and thus the lender will offer the maximum non-rationing probability i.e. $\pi_{Ht} = 1$. From (2.46) we find that

$$q_{Ht} = \frac{p_H (p_L - \varepsilon) w_t}{p_L (p_H - \varepsilon)}$$

Thus, we find that the equilibrium contract is

$$C_H^r = (R_{Ht}, q_{Ht}, \pi_{Ht}) = \left( \frac{Q\varepsilon\rho_{t+1}}{p_H}, \frac{p_H (p_L - \varepsilon) w_t}{p_L (p_H - \varepsilon)}, 1 \right)$$

The interpretation of these results is straightforward. If the $IC_L$ constraint binds and the $IC_H$ constraint does not bind then the low-risk borrower gets his first-best contract but the high-risk borrower is offered a second-best contract. If we take the $IC_L$ as equality and we substitute the terms of $C_H^r$ and $C_L$ then we find that the $IC_L$ is binding.

Substituting the terms of $C_H^r$ and $C_L$ in (2.39), we find that the $IC_H$ is also binding. This contradicts the original assumption. Thus, Case 2 cannot be true. ∎

**Proof. 3: Derivation of Proposition 2.1**

The participation constraints, which ensure that the type $L$ and type $H$ respectively borrowers will prefer to take the loan offered to them rather than use their home technology are

$$\begin{gathered} \phi \left[\pi_{Lt}^n p_L \left(Q\rho_{t+1} - R_{Lt}^n\right) q_{Lt}^n + (1 - \pi_{Lt}^n) \beta_L\right] + \\ (1 - \phi) \left[\pi_{Lt}^s p_L \left(Q\rho_{t+1} - R_{Lt}^s\right) q_{Lt}^s + (1 - \pi_{Lt}^s) \beta_L\right] \geq \beta_L \end{gathered}$$

and

$$\pi_{Ht} p_H \left(Q\rho_{t+1} - R_{Ht}\right) q_{Ht} \geq 0$$

The incentive compatibility constraint for type $L$ and type $H$ respectively are:

$$\begin{aligned}
& \phi\left[\pi_{Lt}^{n} p_L \left(Q\rho_{t+1} - R_{Lt}^{n}\right) q_{Lt}^{n} + \left(1 - \pi_{Lt}^{n}\right)\beta_L\right] + \\
& (1-\phi)\left[\pi_{Lt}^{s} p_L \left(Q\rho_{t+1} - R_{Lt}^{s}\right) q_{Lt}^{s} + \left(1 - \pi_{Lt}^{s}\right)\beta_L\right] \\
\geq\ & \pi_{Ht} p_L \left(Q\rho_{t+1} - R_{Ht}\right) q_{Ht} + \left(1 - \pi_{Ht}\right)\beta_L
\end{aligned}$$

and

$$\pi_{Ht} p_H \left(Q\rho_{t+1} - R_{Ht}\right) q_{Ht} \geq \phi \pi_{Lt}^{n} p_H \left(Q\rho_{t+1} - R_{Lt}^{n}\right) q_{Lt}^{n}$$

To derive the optimal contract, it is assumed that the incentive compatibility constraint of the high risk borrower is binding and the one for the low risk type is non binding. Similarly, both participation constraints are assumed to be non binding and thus are being ignored during the maximization procedure. After deriving the equilibrium contracts it is verified that both assumptions are true.

Substituting the zero profit condition (2.52) in the objective function (2.50) we obtain:

$$\begin{aligned}
EP_L\left(C_L^{s}\right) &= \phi\pi_{Lt}^{n}\left(p_L Q\rho_{t+1} q_{Lt}^{n} - \beta_L - q_{Lt}^{n} Q\varepsilon\rho_{t+1}\right) + \phi\beta_L \\
&\quad + (1-\phi)\left(p_L q_{Lt}^{s} Q\rho_{t+1} - q_{Lt}^{s}(1+\gamma) Q\varepsilon\rho_{t+1}\right) \qquad (2.49)
\end{aligned}$$

Given that a high risk borrower gets his first best contract
$C_H = \left(R_{Ht}, q_{Ht}, \pi_{Ht}\right) = \left(\frac{Q\varepsilon\rho_{t+1}}{p_H}, w_t, 1\right)$
a lender solves the following program to determine the optimal $C_L^{s}$:
Select $R_{Lt}^{s}, R_{Lt}^{n}, q_{Lt}^{s}, q_{Lt}^{n}, \pi_{Lt}^{n}, \phi_t$ to maximize the expected utility of low risk type:

$$EP_L\left(C_L^{s}\right) = \phi\left(\pi_{Lt}^{n} p_L \left(Q\rho_{t+1} - R_{Lt}^{n}\right) q_{Lt}^{n} + \left(1 - \pi_{Lt}^{n}\right)\beta_L\right) + (1-\phi) p_L \left(Q\rho_{t+1} - R_{Lt}^{s}\right) q_{Lt}^{s} \qquad (2.50)$$

subject to the constraints of the model:

$$p_H\left(Q\rho_{t+1} - \frac{Q\varepsilon\rho_{t+1}}{p_H}\right) w_t \geq \phi\pi_{Lt}^{n} p_H \left(Q\rho_{t+1} - R_{Lt}^{n}\right) q_{Lt}^{n} \qquad (2.51)$$

$$\phi\pi_{Lt}^{n}p_{L}q_{Lt}^{n}R_{L}^{n}+(1-\phi)\,p_{L}q_{Lt}^{s}R_{L}^{s}=\phi\pi_{Lt}^{n}q_{Lt}^{n}Q\varepsilon\rho_{t+1}+(1-\phi)\,q_{Lt}^{s}\,(1+\gamma)\,Q\varepsilon\rho_{t+1} \quad (2.52)$$

$$0\leq R_{Lt}^{s}$$

$$0\leq R_{Lt}^{n}$$

$$0\leq q_{Lt}^{n}\leq w_{t}$$

$$0\leq q_{Lt}^{s}\leq\frac{w_{t}}{1+\gamma}$$

$$0\leq\pi_{Lt}^{n}\leq1$$

$$0\leq\phi_{t}\leq1$$

Notice that (2.51) is the incentive compatibility constraint for type $H$ where we have substituted the contract terms of $C_H$.

Above maximization problem can be simplified:

Claim 1: $q_{Lt}^{s}=\frac{w_t}{1+\gamma}$

Since $q_{Lt}^{s}$ does not appear in the $\text{IC}_H$, the lender can increase the return of type $L$ borrower by pushing $q_{Lt}^{s}$ to its upper limit.

Claim 2: $R_{L}^{s}=0$

None of the interest rates appears in the simplified version of the objective function but $R_{Lt}^{n}$ appears (negatively) on the right hand side of the incentive compatibility constraint of the high-risk borrower. So, the lender should set $R_{L}^{n}$ as high as possible in order to deter an $H$ type borrower from applying for a $C_L$ contract. It is obvious from the zero-profit condition that this implies that $R_{L}^{s}$ should be set as low as possible.

Substituting the expressions for $q_{Lt}^{s}$ and $R_{L}^{s}$ in the zero profit condition (2.52):

$$R_{L}^{n}=\frac{\left(\phi\pi_{Lt}^{n}q_{Lt}^{n}+(1-\phi)\,w_{t}\right)Q\varepsilon\rho_{t+1}}{\phi\pi_{Lt}^{n}p_{L}q_{Lt}^{n}} \quad (2.53)$$

If we assume that the $IC_H$ given by (2.51) is binding and substitute (2.53) we can solve for $q^n_{Lt}$:

$$q^n_{Lt} = \frac{\left(\left(1-\frac{\varepsilon}{p_H}\right)w_t + \frac{(1-\phi)w_t\varepsilon}{p_L}\right)}{\phi\pi^n_L\left(1-\frac{\varepsilon}{p_L}\right)} \tag{2.54}$$

Then, the feasibility constraint implies that:

$$\pi^n_L \geq \frac{\left(\left(1-\frac{\varepsilon}{p_H}\right) + \frac{(1-\phi)\varepsilon}{p_L}\right)}{\phi\left(1-\frac{\varepsilon}{p_L}\right)} \tag{2.55}$$

Substituting $q^s_{Lt}$ and $q^n_{Lt}$ given by (2.54) in (2.49) we get:

$$\begin{aligned} EP_L\left(C^s_L\right) &= p_L Q\rho_{t+1}\left(\left(1-\frac{\varepsilon}{p_H}\right)w_t + \frac{(1-\phi)\,w_t\varepsilon}{p_L}\right) - \phi\pi^n_{Lt}\beta_L \\ &\quad +\phi\beta_L + (1-\phi)\,Q\rho_{t+1}\frac{w_t}{1+\gamma}\left(p_L-(1+\gamma)\,\varepsilon\right) \end{aligned} \tag{2.56}$$

Because $\frac{\partial EP_L(C^s_L)}{\partial\pi^n_L} = -\phi\beta_L \leq 0$, the expected payoff for the low-risk borrower is (at equilibrium) decreasing to $\pi^n_L$ and thus (2.55) holds with equality. Thus, the equilibrium value of $\pi^n_L$ is

$$\pi^n_L = \frac{\left(\left(1-\frac{\varepsilon}{p_H}\right) + \frac{(1-\phi)\varepsilon}{p_L}\right)}{\phi\left(1-\frac{\varepsilon}{p_L}\right)} \tag{2.57}$$

However, $\pi^n_L \leq 1$ which implies that

$$1-\frac{\varepsilon}{p_H}+\frac{\varepsilon}{p_L} \leq \phi \tag{2.58}$$

In order to calculate whether the expected payoff for the low risk borrower is greater under rationing or screening, we need to calculate the derivative of (2.56) with respect to $\phi$. So, if we substitute the equilibrium value of $\pi^n_{Lt}$ in (2.56) we obtain:

$$EP_L\left(C_L^s\right) = Q\rho_{t+1}\left(\left(1-\frac{\varepsilon}{p_H}\right)w_t + \frac{(1-\phi)\,w_t\varepsilon}{p_L}\right)p_L - \frac{\left(\left(1-\frac{\varepsilon}{p_H}\right)+\frac{(1-\phi)\varepsilon}{p_L}\right)}{\left(1-\frac{\varepsilon}{p_L}\right)}\beta_L$$
$$+\phi\beta_L + (1-\phi)\,Q\rho_{t+1}\frac{w_t}{1+\gamma}\left(p_L-(1+\gamma)\,\varepsilon\right)$$

and thus the derivative is:

$$\frac{\partial EP_L\left(C_L^s\right)}{\partial\phi} = \frac{p_L}{p_L-\varepsilon}\beta_L - Q\rho_{t+1}\frac{w_t}{1+\gamma}p_L$$

So, if

$$\left(p_L-\varepsilon\right)Q\rho_{t+1}\frac{w_t}{1+\gamma} > \beta_L$$

then $\frac{\partial EP_L\left(C_L^s\right)}{\partial\phi} < 0$. In this case, the expected payoff of the low risk borrower is (at equilibrium) strictly decreasing to $\phi_t$ and thus (2.58) holds with equality i.e. *screening dominates.* So, for $\phi_t = 1 - \frac{\varepsilon}{p_H} + \frac{\varepsilon}{p_L}$, (2.57) yields $\pi_L^n = 1$, (2.54) yields $q_{Lt}^n = w_t$ and (2.53) yields $R_L^n = \frac{Q\varepsilon\rho_{t+1}}{\phi p_L}$

However, if

$$\left(p_L-\varepsilon\right)Q\rho_{t+1}\frac{w_t}{1+\gamma} < \beta_L$$

then $\frac{\partial EP_L\left(C_L^s\right)}{\partial\phi} > 0$ and the expected payoff of the low risk borrower is (at equilibrium) strictly increasing to $\phi_t$. So, the non screening probability takes its maximum value i.e. $\phi = 1$ and there is no screening. Moreover, (2.57) yields $\pi_L^n = \frac{\left(1-\frac{\varepsilon}{p_H}\right)}{\left(1-\frac{\varepsilon}{p_L}\right)}$, (2.54) yields $q_{Lt}^n = w_t$ and (2.53) yields $R_L^n = \frac{Q\varepsilon\rho_{t+1}}{p_L}$ i.e. the equilibrium contracts terms of the rationing regime occur i.e. *rationing dominates.*

### Participation Constraints

The high risk borrowers get the rationing contract. In Proof 1 we have already shown that the participation constraint of the high risk borrower is not binding in this case.

The participation constraint for the low risk borrowers if we substitute the equilibrium contract terms but $\phi$ and do some algebraic manipulation becomes:

$$\frac{p_L - \varepsilon}{1+\gamma} Q\rho_{t+1} w_t + Q\rho_{t+1} w_t \left( \frac{(\phi p_L - \varepsilon)\gamma}{1+\gamma} \right) \geq \beta_L$$

Since $\frac{p_L - \varepsilon}{1+\gamma} Q\rho_{t+1} w_t > \beta_L$ and $(\phi p_L - \varepsilon) = \frac{p_L(p_H - \varepsilon)}{p_H} > 0$, the participation constraint for the low risk borrowers is not binding.

### Incentive Compatibility Constraints

We want to show that the $IC_H$ constraint binds and the $IC_L$ constraint does not bind. If we substitute the equilibrium contract terms in the incentive compatibility constraint for the type $L$ we obtain:

$$\left( \frac{\varepsilon}{p_H} - \frac{\varepsilon}{p_L} \right) \frac{1}{1+\gamma} > 0$$

i.e. the incentive compatibility constraint for the type $L$ is not binding. Similarly, we find that the incentive compatibility constraint for type $H$ holds with equality for the equilibrium contract terms.

### Derivation of the switching point between the screening and the rationing regime

A different way to verify that $\beta^* = \frac{p_L - \varepsilon}{1+\gamma} Q\rho_{t+1} w_t$ is the value for which the lender is indifferent between offering the rationing or the screening contract to the low risk borrowers, is to compare the expected payoff from the screening contract (given by (2.50)) to the expected payoff from the rationing contract (given by (2.38)) after substituting the equilibrium value of $\phi$. We find that $EP_L(C_L^s) > EP_L(C_L^r)$ when $(p_L - \varepsilon) Q\rho_{t+1} \frac{w_t}{1+\gamma} > \beta_L$ indeed. ∎

**Proof. 4: Derivation of Proposition 2.2**

The participation constraints, which ensure that the type $L$ and type $H$ respectively borrowers will prefer to take the loan offered to them rather than use their home technology are:

$$\pi_{lt}^{s} p(l/L) p_L \left(Q\rho_{t+1} - R_l^{s}\right) q_{lt}^{s} + (1 - \pi_{lt}^{s}) p(l/L) \beta_L \geq \beta_L$$

$$\pi_{Ht} p_H \left(Q\rho_{t+1} - R_{Ht}\right) q_{Ht} \geq 0$$

The incentive compatibility constraints for type $L$ and type $H$ respectively are:

$$\begin{aligned}\pi_{lt}^{s} p(l/L) p_L \left(Q\rho_{t+1} - R_l^{s}\right) q_{lt}^{s} + (1 - \pi_{lt}^{s}) p(l/L) \beta_L \\ \geq \pi_{Ht}^{r} p_L \left(Q\rho_{t+1} - R_{Ht}^{r}\right) q_{Ht}^{r} + (1 - \pi_{Ht}^{r}) \beta_L\end{aligned} \tag{2.59}$$

$$\pi_{Ht}^{r} p_H \left(Q\rho_{t+1} - R_{Ht}^{r}\right) q_{Ht}^{r} \geq \pi_{lt}^{s} p(l/H) p_H \left(Q\rho_{t+1} - R_l^{s}\right) q_{lt}^{s} \tag{2.60}$$

Expression (2.59) has the following interpretation. With probability $\pi_{lt}^{s}$ the lender gives out a loan of amount $q_{lt}^{s}$ charging the borrower $R_l^{s}$. Of course, the probability of yielding the return depends on the real entrepreneurial ability of the borrower $p_L$. If the borrower is rationed, he produces according to his home production technology and gets $\beta_L$. In order for a low-risk borrower to reveal his type, this expected payoff should be at least as high as the expected payoff if he conceals his type. The expression (2.60) can be interpreted similarly.

Given that a high risk borrower gets his first-best contract $C_H = (R_{Ht}, q_{Ht}, \pi_{Ht}) = \left(\frac{Q\varepsilon\rho_{t+1}}{p_H}, w_t, 1\right)$,a lender solves the following program to determine the optimal $C_l^{s} = (R_{lt}^{s}, q_{lt}^{s}, \pi_{lt}^{s})$:Select $R_{lt}^{s}, q_{lt}^{s}$ and $\pi_{lt}^{s}$ to maximize the expected utility of the low risk type i.e.:

$$\text{Maximize } EP_l\left(C_l^{s}\right) = \pi_{lt}^{s} p_L \left(Q\rho_{t+1} - R_l^{s}\right) q_{lt}^{s} + (1 - \pi_{lt}^{s}) \beta_L \tag{2.61}$$

subject to the constraints of the model:

$$\left(Q\rho_{t+1} - \frac{Q\varepsilon\rho_{t+1}}{p_H}\right) w_t \geq \pi_{lt}^s (1-\delta)\left(Q\rho_{t+1} - R_l^s\right) q_{lt}^s \tag{2.62}$$

$$\pi_{lt}^s q_{lt}^s R_l^s p_L = \pi_{lt}^s q_{lt}^s (1+c)\, Q\varepsilon\rho_{t+1} \tag{2.63}$$

$$0 \leq R_{lt}^s$$

$$0 \leq q_{lt}^s \leq \frac{w_t}{1+c} \tag{2.64}$$

$$0 \leq \pi_{lt}^s \leq 1 \tag{2.65}$$

Notice that (2.62) is the incentive compatibility constraints for type $H$ after substituting the conditional probabilities and the equilibrium terms of $C_H$. We derive the equilibrium contracts by ignoring the non binding participation constraints and at the end we check that they are not binding. Similarly, we assume that the incentive compatibility constraint of the high risk borrowers (whose contract is not affected by considerations of self-selection) is binding. It follows that the incentive compatibility constraint of the low risk borrowers is not binding. So, we derive the equilibrium contracts by ignoring the non binding incentive compatibility constraint of the $L$ type borrowers and at the end we check that the condition holds.

If we solve (2.63) for $R_l^s$ we find that:

$$R_l^s = \frac{(1+c)\, Q\varepsilon\rho_{t+1}}{p_L} \tag{2.66}$$

If we assume that the incentive compatibility of the high-risk borrower is binding, substitute (2.66) and solve (2.62) for $q_{lt}^s$ we obtain:

$$q_{lt}^s = \frac{\left(1 - \frac{\varepsilon}{p_H}\right) w_t}{\pi_{lt}^s (1-\delta)\left(1 - \frac{(1+c)\varepsilon}{p_L}\right)} \tag{2.67}$$

for $\pi_{lt}^s \neq 0$, $\delta \neq 1$ and $\frac{(1+c)\varepsilon}{p_L} \neq 1$.

The feasibility constraint (2.64) implies that:

$$\pi_{lt}^{s} \geq \frac{\left(1-\frac{\varepsilon}{p_H}\right)(1+c)}{(1-\delta)\left(1-\frac{(1+c)\varepsilon}{p_L}\right)} \tag{2.68}$$

If we substitute the zero profit condition (2.63) and expression (2.67) into the objective function (2.61), we obtain:

$$EP_l\left(C_l^s\right) = \frac{\left(1-\frac{\varepsilon}{p_H}\right)w_t}{(1-\delta)\left(1-\frac{(1+c)\varepsilon}{p_L}\right)}Q\rho_{t+1}\left(p_L-(1+c)\varepsilon\right)+\left(1-\pi_{lt}^{s}\right)\beta_L \tag{2.69}$$

At equilibrium, (2.69) is strictly decreasing to $\pi_{lt}^{s}$ since $\frac{\partial EP_l\left(C_l^s\right)}{\partial \pi_{lt}^{s}} = -\beta_L < 0$. So, (2.68) holds with equality i.e.

$$\pi_{lt}^{s} = \frac{\left(1-\frac{\varepsilon}{p_H}\right)(1+c)}{(1-\delta)\left(1-\frac{(1+c)\varepsilon}{p_L}\right)} \tag{2.70}$$

However, we need to check that (2.70) satisfies the assumption $0 \leq \pi_{lt}^{s} \leq 1$. Since the numerator of the right hand side of (2.70) is positive and $\delta < 1$, we need to look at the sign of the expression $\left(1-\frac{(1+c)\varepsilon}{p_L}\right)$.

**Case 1: Developed Economy ($p_L > (1+c)\varepsilon$)**

In $p_L > (1+c)\varepsilon$, the right hand side of (2.70) is always non negative. However, there are the following cases:

**(1.i)** If the right hand side of (2.70) is equal to zero then (2.67) implies that the quantity offered becomes undefinable. However, since rationing is certain, the lender can offer any amount of credit if there is no probability of granting the loan. Hence, the feasibility condition (2.64) is not relevant anymore and thus the restriction (2.68) can be relaxed. There is no screening contract that satisfies the constraints of the problem.

**(1.ii)** Another scenario for a developed economy is that $0 < \pi_{lt}^{s} < 1$. Assuming that the right hand side of (2.70) is between zero and one is equivalent to:

$$0 \leq c < \frac{p_H (p_L - \varepsilon)(1 - \delta^{s_1}) - p_L (p_H - \varepsilon)}{(p_L (p_H - \varepsilon) + \varepsilon p_H (1 - \delta^{s_1}))} \tag{2.71}$$

We also need to take into consideration the definition of the developed economy i.e. $p_L > (1 + c)\varepsilon$ or

$$c < \frac{p_L}{\varepsilon} - 1 \tag{2.72}$$

If we compare (2.71) and (2.72) we find that (2.71) is the most restrictive constraint. Thus, the constraint $0 < \pi_{lt}^{s} < 1$ implies that screening cost's range of values is $c \in [0, \widetilde{c})$, where $\widetilde{c}$ is:

$$\widetilde{c} = \frac{p_H (p_L - \varepsilon)(1 - \delta^{s_1}) - p_L (p_H - \varepsilon)}{(p_L (p_H - \varepsilon) + \varepsilon p_H (1 - \delta^{s_1}))} \tag{2.73}$$

The right hand side of the last inequality has to be positive since $c \geq 0$. In other words, since the denominator is always positive, we need:

$$0 \leq \delta^{s_1} < \frac{(p_L - p_H)\varepsilon}{(p_L - \varepsilon) p_H} \tag{2.74}$$

Notice that (2.74) is binding since the RHS is smaller than one.

If $R_l^{s_1}$, $\pi_{lt}^{s_1}$, $q_{lt}^{s_1}$ are the equilibrium values of the non-rationing probability and the amount of loan, then we obtain their values from (2.66), (2.70) and (2.68) respectively. Thus, when $c \in [0, \widetilde{c})$ and (2.74) holds, the equilibrium contract offered is:

$$C_l^{s_1} = \left(R_l^{s_1}, q_{lt}^{s_1}, \pi_{lt}^{s_1}\right) = \left(\frac{(1+c)\, Q \varepsilon \rho_{t+1}}{p_L}, \frac{w_t}{1+c}, \frac{\left(1 - \frac{\varepsilon}{p_H}\right)(1+c)}{(1 - \delta^{s_1})\left(1 - \frac{(1+c)\varepsilon}{p_L}\right)}\right)$$

.

Obviously, if $c \notin [0, \widetilde{c})$ or (2.74) does not hold, there are no $R_l^{s}, q_{lt}^{s}, \pi_{lt}^{s}$ which satisfy $\pi_{lt}^{s} < 1$ if $p_L > (1 + c)\varepsilon$.

**(1.iii)** The next scenario for a developed economy is that the right hand side of

(2.70) is equal to one. In this case from (2.70) we obtain:

$$\frac{\left(1-\frac{\varepsilon}{p_H}\right)}{\left(1-\delta^{s_2}\right)\left(1-\frac{(1+c)\varepsilon}{p_L}\right)}=\frac{1}{(1+c)} \tag{2.75}$$

and substituting (2.75) in (2.67) we find that:

$$q_{lt}^{s}=\frac{w_t}{(1+c)}$$

If $R_l^{s2}$, $q_{lt}^{s2}$ and $\pi_{lt}^{s2}$ are the equilibrium contract terms, then the lender offers the following contract:

$$C_l^{s2}=\left(R_l^{s2},q_{lt}^{s2},\pi_{lt}^{s2}\right)=\left(\frac{(1+c)\,Q\varepsilon\rho_{t+1}}{p_L},\frac{w_t}{(1+c)},1\right)$$

**(1.iv)** Lastly, when the right hand side of (2.70)is greater than one, the assumption (2.65) is violated. There is no screening contract that satisfies the constraints of the problem

**Case 2: Undeveloped Economy ($p_L<(1+c)\,\varepsilon$)**

In this case the right hand side of (2.70) is always negative. The assumption (2.65) is violated (and the amount of loan given by (2.67) becomes negative). There is no screening contract that satisfies the constraints of the problem.

### Participation Constraints

In the model of BC, (2.8) implies that the participation constraints for the low risk borrowers holds with strict inequality under both the rationing and the screening regime. However, in our model, (2.8) is a sufficient condition under the rationing regime only. The reason for this is that screening is now compulsory. To understand the difference we need to recall that BC showed that when screening is not compulsory, the optimal screening probability is positive ($\phi^*>0$) i.e. $\phi>0$ is preferred to

$\phi = 0$. In other words, entailing the screening cost is optimal. Since in our model screening is compulsory, assuming that the expected payoff from a loan is increasing to the non-rationing probability and the quantity of the loan i.e. (2.8) and (2.9) hold, is not sufficient anymore (although (2.8) is still valid).

**Case 1: Developed Economy ($p_L > (1+c)\,\varepsilon$)**

**(1.i)**To solve for the low risk borrower's expected payoff we substitute (2.66) in (2.61):

$EP_l\left(C_l^{s3}\right) = \pi_{lt}^{s3} p_L \left(Q\rho_{t+1} - \frac{(1+c)Q\varepsilon\rho_{t+1}}{p_L}\right) q_{lt}^{s3} + \left(1 - \pi_{lt}^{s3}\right)\beta_L$

and since rationing is certain then $\pi_{lt}^{s3} = 0$. So, the expected payoff for $L$ type borrowers is:

$EP_l\left(C_l^{s3}\right) = \beta_L$

i.e. the low-risk borrowers are indifferent between accepting the loan (which is offered to them with zero probability) or using their home technology. However, we assume that the borrowers prefer the contract over their home technology (in a manner similar to the assumption that if a borrower is indifferent between two types of contracts, he chooses the contract designed for his type) which implies that the participation constraint is not binding.

**(1.ii)** The participation constraint is:

$\pi_{lt}^{s} p_L \left(Q\rho_{t+1} - R_l^s\right) q_{lt}^{s} + (1 - \pi_{lt}^{s})\beta_L \geq \beta_L$ or $p_L \left(Q\rho_{t+1} - R_l^s\right) q_{lt}^{s} \geq \beta_L$. However, (2.8) implies that the last constraint holds with strong inequality.

**(1.iii)** This case is identical to (1.ii).

**(1.iv)** This case is identical to (1.i).

For future reference we would like to define the point at which a low risk borrower is indifferent between one of the two screening contract and his home technology. If we substitute the contract terms of $C_l^{s1}$ or $C_l^{s2}$ we see that low risk borrowers always prefer the screening contract to their home technology when $p_L\left(Q\rho_{t+1} - \frac{(1+c)Q\varepsilon\rho_{t+1}}{p_L}\right)\frac{w_t}{1+c} > \beta_L$ Thus, we define:

$$\beta^s = \left(\frac{p_L}{1+c} - \varepsilon\right) Q\rho_{t+1} w_t > \beta_L$$

**Case 2: Undeveloped Economy ($p_L < (1+c)\varepsilon$)**

This case is identical to (1.i).

**Incentive Compatibility Constraints**

**The screening contract $C_l^{s_1}$**

If we substitute the contract terms of $C_l^{s_1}$ in the left hand side of the $IC_L$ given by (2.16) we obtain:

$$\frac{1}{(1-\delta^{s_1})} p_L \left(Q\rho_{t+1} - \frac{Q\varepsilon\rho_{t+1}}{p_H}\right) w_t + \left(1 - \frac{\left(1-\frac{\varepsilon}{p_H}\right)(1+c)}{(1-\delta^{s_1})\left(1-\frac{(1+c)\varepsilon}{p_L}\right)}\right)\beta_L$$
$$> p_L \left(Q\rho_{t+1} - \frac{Q\varepsilon\rho_{t+1}}{p_H}\right) w_t$$

since $\frac{1}{(1-\delta^{s_1})} > 1$ and $0 < \frac{\left(1-\frac{\varepsilon}{p_H}\right)(1+c)}{(1-\delta^{s_1})\left(1-\frac{(1+c)\varepsilon}{p_L}\right)} < 1$

i.e. the $IC_L$ is indeed non-binding.

If we substitute the contract terms of $C_l^{s_1}$ in the girth hand side of the $IC_H$ given by (2.62) we obtain:

$$\frac{\left(1-\frac{\varepsilon}{p_H}\right)}{\left(1-\frac{(1+c)\varepsilon}{p_L}\right)} Q\rho_{t+1}\left(1 - \frac{(1+c)\varepsilon}{p_L}\right) w_t$$
$$= \left(Q\rho_{t+1} - \frac{Q\varepsilon\rho_{t+1}}{p_H}\right) w_t$$

i.e. the $IC_H$ is binding

**The screening contract $C_l^{s_2}$**

If we substitute the contract terms of $C_l^{s_2}$ in the left hand side of the $IC_L$ given by (2.16) we obtain:

$$p_L Q\rho_{t+1}\left(1 - \frac{(1+c)\varepsilon}{p_L}\right)\frac{w_t}{(1+c)}$$

But using (2.75), the last expression becomes

$$p_L Q\rho_{t+1} w_t \frac{\left(1-\frac{\varepsilon}{p_H}\right)}{(1-\delta^{s_2})}$$
$$> p_L \left(Q\rho_{t+1} - \frac{Q\varepsilon\rho_{t+1}}{p_H}\right) w_t$$

i.e. the $IC_L$ is indeed non-binding.

If we substitute the contract terms of $C_l^{s_2}$ in the right hand side of the $IC_H$ given by (2.62) we obtain:

$(1-\delta^{s_2}) Q\rho_{t+1}\left(1-\frac{(1+c)\varepsilon}{p_L}\right)\frac{w_t}{(1+c)}$

But using (2.75)

$= Q\rho_{t+1}\frac{w_t}{(1+c)}\left(1-\frac{\varepsilon}{p_H}\right)(1+c)$

$= \left(Q\rho_{t+1}-\frac{Q\varepsilon\rho_{t+1}}{p_H}\right)w_t$

i.e. the $IC_H$ is binding

**Derivation of the switching points between the screening and the rationing regimes**

**Case 1: Developed Economy ($p_L > (1+c)\varepsilon$)**

**(1.i)** Rationing is certain when lenders offer a screening contract to low risk borrowers. The borrower's expected payoff is higher under $C_L^r$ compared to $C_l^{s_3}$ when:

$\frac{1-\varepsilon/p_H}{1-\varepsilon/p_L}p_L\left(Q\rho_{t+1}-\frac{Q\varepsilon\rho_{t+1}}{p_L}\right)w_t+\left(1-\frac{1-\varepsilon/p_H}{1-\varepsilon/p_L}\right)\beta_L > \beta_L$

or

$p_L\left(Q\rho_{t+1}-\frac{Q\varepsilon\rho_{t+1}}{p_L}\right)w_t > \beta_L$

which is (2.8) for the contract terms of $C_L^r$. Thus, the low risk borrower always prefer the contract $C_L^r$ to $C_l^{s_3}$.

**(1.ii)** The borrower's expected payoff is higher under $C_l^{s_1}$ compared to $C_L^r$ when $EP_l\left(C_l^{s_1}\right) > EP_L\left(C_L^r\right)$ or, after some algebraic manipulation,:

$$\beta^{s_1} = Q\rho_{t+1}w_t\frac{\delta^{s_1}\left(p_L-(1+c)\varepsilon\right)\left(p_L-\varepsilon\right)}{c\left(p_L-\delta^{s_1}\varepsilon\right)+\delta^{s_1}\left(p_L-\varepsilon\right)} > \beta_L$$

Of course, $c\in[0,\widetilde{c})$ and (2.74) should hold. However, above condition is not enough to say that $C_l^{s_1}$ is the equilibrium contract. It is necessary for the borrower to accept the contract in the first place i.e. to prefer $C_l^{s1}$ to his home technology. In other words, the participation constraint of (1.ii) should hold.

From a technical point of view, we need to know how $\beta^{s1}$ compares with $\beta^{s}$ and $\beta^{r}$. We see that $\beta^{s1} < \beta^{s}$ when

$\frac{\delta^{s1}(p_L-(1+c)\varepsilon)(p_L-\varepsilon)}{c(p_L-\delta^{s1}\varepsilon)+\delta^{s1}(p_L-\varepsilon)} < \left(\frac{p_L-\varepsilon(1+c)}{1+c}\right)$

or

$(\delta^{s1}-1)<0$

which is always true. Similarly, $\beta^{s} < \beta^{r}$ when

$\left(\frac{p_L}{(1+c)}-\varepsilon\right) < (p_L-\varepsilon)$

which is always true.

Summarizing, the equilibrium contracts are $C_l^{s1}$ when $\beta_L < \beta^{s1}$ and $C_L^{r}$ when $\beta^{s1} < \beta_L < \beta^{r}$.

**(1.iii)** The borrower's expected payoff is higher for $C_l^{s2}$ compared to $C_L^{r}$ when $EP_l\left(C_l^{s2}\right) > EP_L\left(C_L^{r}\right)$. After some algebraic manipulation we find that this is equivalent to

$Q\rho_{t+1}w_t\left(\frac{1}{(1+c)}\frac{p_Lp_H(p_L-\varepsilon)}{\varepsilon(p_L-p_H)}+\frac{(\varepsilon(p_L-p_H)-p_Lp_H)(p_L-\varepsilon)}{\varepsilon(p_L-p_H)}\right) > \beta_L$

So, the expected payoff from $C_l^{s2}$is higher than $C_L^{r}$ when

$$\beta^{s2} = Q\rho_{t+1}w_t\left(\frac{1}{(1+c)}+\frac{\varepsilon}{p_H}-\frac{\varepsilon}{p_L}-1\right)\frac{p_Lp_H\left(p_L-\varepsilon\right)}{\varepsilon\left(p_L-p_H\right)} > \beta_L$$

The last inequality implies that when the screening contract is preferred by the low risk borrowers, the screening cost has to be small (since for high values of c, $\beta^{s2}$ is negative).

However, it is a necessary condition that the participation constraints for both $C_l^{s2}$ and $C_L^{r}$ contracts hold. Technically speaking, we need to know how $\beta^{s2}$ compares with $\beta^{s}$ and $\beta^{r}$. We see that $\beta^{s2} < \beta^{s}$ when:

$p_LQ\rho_{t+1}w_t\frac{1-\frac{\varepsilon}{p_H}}{\frac{\varepsilon}{p_H}-\frac{\varepsilon}{p_L}}\left(\frac{-c}{(1+c)}\right) < 0$which is always true. Since, we have already shown that $\beta^{s} < \beta^{r}$ we can summarize that the equilibrium contracts are $C_l^{s2}$ when $\beta_L < \beta^{s2}$ and $C_L^{r}$ when $\beta^{s2} < \beta_L < \beta^{r}$.

**(1.iv)**

This case is identical to(1.i).

**Case 2: Undeveloped Economy** $(p_L < (1+c)\,\varepsilon)$

This case is identical to (1.i) ■

**Proof. 5: The quality of screening for $C_l^{s_2}$ is higher than for $C_l^{s_1}$**

The contracts $C_l^{s_1}$ and $C_l^{s_2}$ are based on the value of the right hand side of (2.70). Up to now, we have been assuming that $\varepsilon$, $p_H$ and $p_L$ are the same under all regimes (they don't vary within a country, across countries and over time). So, what can differ between $C_l^{s_1}$ and $C_l^{s_2}$, are the exogenous screening effort and the screening cost.

The simplest approach is to assume that the two screening contracts entail the same level of screening cost. Thus, for a given level of screening cost $c$ the screening quality is $\delta^{s_1}$ and $\delta^{s_2}$ for the contracts $C_l^{s_1}$ and $C_l^{s_2}$ respectively. Then, since the RHS of (2.70) has to lie between zero and one for $C_l^{s_1}$ but has to equal one for $C_l^{s_2}$, then $\pi_{lt}^{s_1} < \pi_{lt}^{s_2}$ when $\delta^{s_2} > \delta^{s_1}$. This result is intuitive. Since the screening contract $C_l^{s_1}$ has a positive probability of rationing whereas there is no rationing in $C_l^{s_2}$, it is reasonable to expect that if the screening cost is assumed to be the same under both $C_l^{s_1}$ and $C_l^{s_2}$ contracts, the higher quality of screening $\delta^{s_2}$ allows the lenders to never ration the borrowers that approach them.

However, if we assume that the two screening contracts entail same level of screening quality, results are counter-intuitive. Specifically, for a given level of $\delta$ the screening cost for the contracts $C_l^{s_1}$ and $C_l^{s_2}$ is $c^{s_1}$ and $c^{s_2}$ respectively. In that case, $\pi_{lt}^{s_1} < \pi_{lt}^{s_2}$ when $c^{s_1} < c^{s_2}$. However, there is no reason to believe that giving more loans should lead to higher proportional screening cost. Furthermore, if the two screening contracts entail different screening cost and quality of screening, then $\pi_{lt}^{s_1} < \pi_{lt}^{s_2}$ when $\frac{(1+c^{s_1}(\delta^{s_1}))}{(1-\delta^{s_1})(p_L-(1+c^{s_1}(\delta^{s_1}))\varepsilon)} < \frac{(1+c^{s_2}(\delta^{s_2}))}{(1-\delta^{s_2})(p_L-(1+c^{s_2}(\delta^{s_2}))\varepsilon)}$ which is not very intuitive ■

**Proof. 6: The non-rationing probability for $C_l^{s_1}$ is greater than for $C_L^r$**

$$\pi_{lt}^{s_1} - \pi_{Lt}^{r}$$

$$= \frac{\left(1-\frac{\varepsilon}{p_H}\right)(1+c)}{(1-\delta^{s_1})\left(1-\frac{(1+c)\varepsilon}{p_L}\right)} - \frac{\left(1-\frac{\varepsilon}{p_H}\right)}{\left(1-\frac{\varepsilon}{p_L}\right)}$$

$$= \frac{\left(1-\frac{\varepsilon}{p_H}\right)(1+c)\left(1-\frac{\varepsilon}{p_L}\right)-\left(1-\frac{\varepsilon}{p_H}\right)(1-\delta^{s_1})\left(1-\frac{(1+c)\varepsilon}{p_L}\right)}{(1-\delta^{s_1})\left(1-\frac{(1+c)\varepsilon}{p_L}\right)\left(1-\frac{\varepsilon}{p_L}\right)}$$

$$= \frac{\left(1-\frac{\varepsilon}{p_H}\right)\left((1+c)\left(1-\frac{\varepsilon}{p_L}\right)-(1-\delta^{s_1})\left(1-\frac{(1+c)\varepsilon}{p_L}\right)\right)}{(1-\delta^{s_1})\left(1-\frac{(1+c)\varepsilon}{p_L}\right)\left(1-\frac{\varepsilon}{p_L}\right)}$$

$$= \frac{(p_H-\varepsilon)p_L(\delta^{s_1}(p_L-\varepsilon)+c(p_L-\delta^{s_1}\varepsilon))}{(1-\delta^{s_1})(p_L-(1+c)\varepsilon)p_H(p_L-\varepsilon)} > 0 \quad \blacksquare$$

**Proof. 7. Comparative statics of the critical value of $\delta$ which tips an economy from screening into rationing when $\pi_{lt}^{s} = 1$**

When $\pi_{lt}^{s} = 1$, (2.70) can be re-arranged as follows: $\frac{\left(1-\frac{\varepsilon}{p_H}\right)}{(1-\delta^{s_2})} = \frac{\left(1-\frac{(1+c)\varepsilon}{p_L}\right)}{(1+c)}$. Substituting this expression in $EP_l\left(C_l^{s_1}\right) = EP_L\left(C_L^r\right)$ i.e. the condition of indifference between the relevant screening contract and the rationing contract we obtain: $\delta = 1 - \frac{1-\frac{\varepsilon}{p_H}}{1-\frac{\varepsilon}{p_H}+\frac{1}{Q\rho p_L w_t}\frac{\beta_L}{-\frac{\varepsilon}{p_L}+1}\left(\frac{\varepsilon}{p_H}-\frac{\varepsilon}{p_L}\right)}$. This result establishes the independence of the critical level of the quality of screening from the level of the screening cost. It is easy to show that the this is equivalent to the independence of the critical value of $c$ which tips an economy from screening into rationing from $\delta$. $\blacksquare$

**Proof. 8: Derivation of dynamic paths and their comparative statics**

**Case 2: $(C_H, C_L^s)$**

The capital stock at $t+1$ comes from the high-risk borrowers that were successful in running their investment project $0.5\lambda p_H$, from the low-risk borrowers who where screened and were successful in their investment $0.5\,(1-\lambda)\,p_L\,(1-\phi)$ and from the low-risk borrowers who where not screened and were successful in their investment $0.5(1-\lambda)p_L\phi$. Thus, the per firm capital stock is:

$$\begin{aligned} K_{t+1}^{s} &= 0.5\lambda p_H Q w_t + 0.5(1-\lambda)p_L(1-\phi)Q\frac{w_t}{1+\gamma} + 0.5(1-\lambda)p_L\phi Q w_t \\ &= 0.5 Q w_t\left(\lambda p_H + (1-\lambda)p_L\phi + (1-\lambda)\frac{1}{1+\gamma}p_L(1-\phi)\right) \end{aligned}$$

Thus, the per firm capital stock is:

$$k_{t+1}^{s} = Q w_t\left(\lambda p_H + (1-\lambda)p_L\phi + (1-\lambda)\frac{1}{1+\gamma}p_L(1-\phi)\right)$$

or after substituting for the equilibrium $w_t$:

$$k_{t+1}^{s} = Q(1-\theta)k_t^{\theta}\left(\lambda p_H + (1-\lambda)p_L\frac{1+\gamma\phi}{1+\gamma}\right) = Bk_t^{\theta}$$

where $B = Q(1-\theta)k_t^{\theta}\left(\lambda p_H + (1-\lambda)p_L\frac{1+\gamma\phi}{1+\gamma}\right)$

**Comparative Statics**

$\frac{\partial B}{\partial\gamma} = Q(1-\theta)(1-\lambda)p_L\frac{\phi-1}{(1+\gamma)^2} < 0$

$\frac{\partial B}{\partial\phi} = Q(1-\theta)(1-\lambda)p_L\frac{\gamma}{1+\gamma} > 0$

**Case 3:** $(C_H, C_l^{s1})$

The capital stock at the second period comes from the successful high-risk borrowers $0.5\lambda p_H$, from the low-risk borrowers who where screened, not rationed and successful in their investment $0.5(1-\lambda)p_L\pi_{lt}^{s1}$. Moreover, there are some lenders that converted their wages into capital after rationing some low-risk borrowers $0.5(1-\lambda)$ $\left(1-\pi_{lt}^{s1}\right)$. Note that this last imply a dead-weight loss $0.5(1-\lambda)\left(1-\pi_{lt}^{s1}\right)Qw_t c$ which was not present in the case of perfect screening. The value of the capital stock in $t+1$ is:

$$\begin{aligned}K_{t+1}^{s1} &= 0.5\lambda p_H Q w_t + 0.5\left(1-\lambda\right) p_L \pi_{lt}^{s1} Q \frac{w_t}{1+c} + 0.5\left(1-\lambda\right)\left(1-\pi_{lt}^{s1}\right) Q \varepsilon \frac{w_t}{1+c} \\ &= 0.5 Q w_t \left(\lambda p_H + \left(1-\lambda\right) p_L \pi_{lt}^{s1} \frac{1}{1+c} + \left(1-\lambda\right)\left(1-\pi_{lt}^{s1}\right) \varepsilon \frac{1}{1+c}\right)\end{aligned}$$

Thus, the per firm capital stock is:

$$k_{t+1}^{s1} = Q w_t \left(\lambda p_H + \left(1-\lambda\right) p_L \pi_{lt}^{s1} \frac{1}{1+c} + \left(1-\lambda\right)\left(1-\pi_{lt}^{s1}\right) \varepsilon \frac{1}{1+c}\right)$$

or after substituting for the equilibrium $w_t = \left(1-\theta\right) k_t^{\theta}$:

$$k_{t+1}^{s1} = Q\left(1-\theta\right) k_t^{\theta} \left(\lambda p_H + \left(1-\lambda\right) p_L \pi_{lt}^{s1} \frac{1}{1+c} + \left(1-\lambda\right)\left(1-\pi_{lt}^{s1}\right) \varepsilon \frac{1}{1+c}\right) = D k_t^{\theta}$$

where $D = Q\left(1-\theta\right)\left(\lambda p_H + \left(1-\lambda\right) p_L \pi_{lt}^{s1} \frac{1}{1+c} + \left(1-\lambda\right)\left(1-\pi_{lt}^{s1}\right) \varepsilon \frac{1}{1+c}\right)$

**Comparative Statics**

$$\frac{\partial D}{\partial \delta^{s1}} = \frac{1}{\left(1-\delta^{s1}\right)^2} \frac{Q(1-\theta)(1-\lambda)\left(1-\frac{\varepsilon}{p_H}\right)(p_L-\varepsilon)}{\left(1-\frac{(1+c)\varepsilon}{p_L}\right)} > 0$$

$$\frac{\partial D}{\partial \pi_{lt}^{s1}} = Q\left(1-\theta\right)\left(1-\lambda\right)\frac{1}{1+c}\left(p_L-\varepsilon\right) > 0$$

$$\frac{\partial \pi_{lt}^{s1}}{\partial c} = \frac{\left(1-\frac{\varepsilon}{p_H}\right) p_L}{\left(1-\delta^{s1}\right)} \frac{p_L}{\left(p_L-(1+c)\varepsilon\right)^2} > 0$$

Finally, we want to calculate the derivative of $k_{t+1}^{s1}$ with respect to the screening cost. It is worth noting that since the derivation of the contract terms of $C_l^{s1}$ is based on the assumption that $0 < \pi_{lt}^{s2} < 1$, $c$ and $\delta^{s1}$ should not be considered independent for the purpose of comparative static analysis. In other words, we want to calculate the effect of a change in $\delta^{s2}$ on $k_{t+1}^{s2}$, conditional on $c$ satisfying the requirement for $0 < \pi_{lt}^{s2} < 1$ throughout. The derivative is:

$$\frac{\partial D}{\partial c} = Q\left(1-\theta\right)\left(1-\lambda\right)\varepsilon\left(\frac{\left(1-\frac{\varepsilon}{p_H}\right)(p_L-\varepsilon)p_L}{\left(1-\delta^{s1}\right)} \frac{1}{\left(p_L-(1+c)\varepsilon\right)^2} - \frac{1}{(1+c)^2}\right) \lesseqgtr 0$$

To show that the last derivative takes both positive and negative values is equal to proving that the last parentheses of the above expression takes both positive and negative values or $f(c) \lesseqgtr 0$, where:

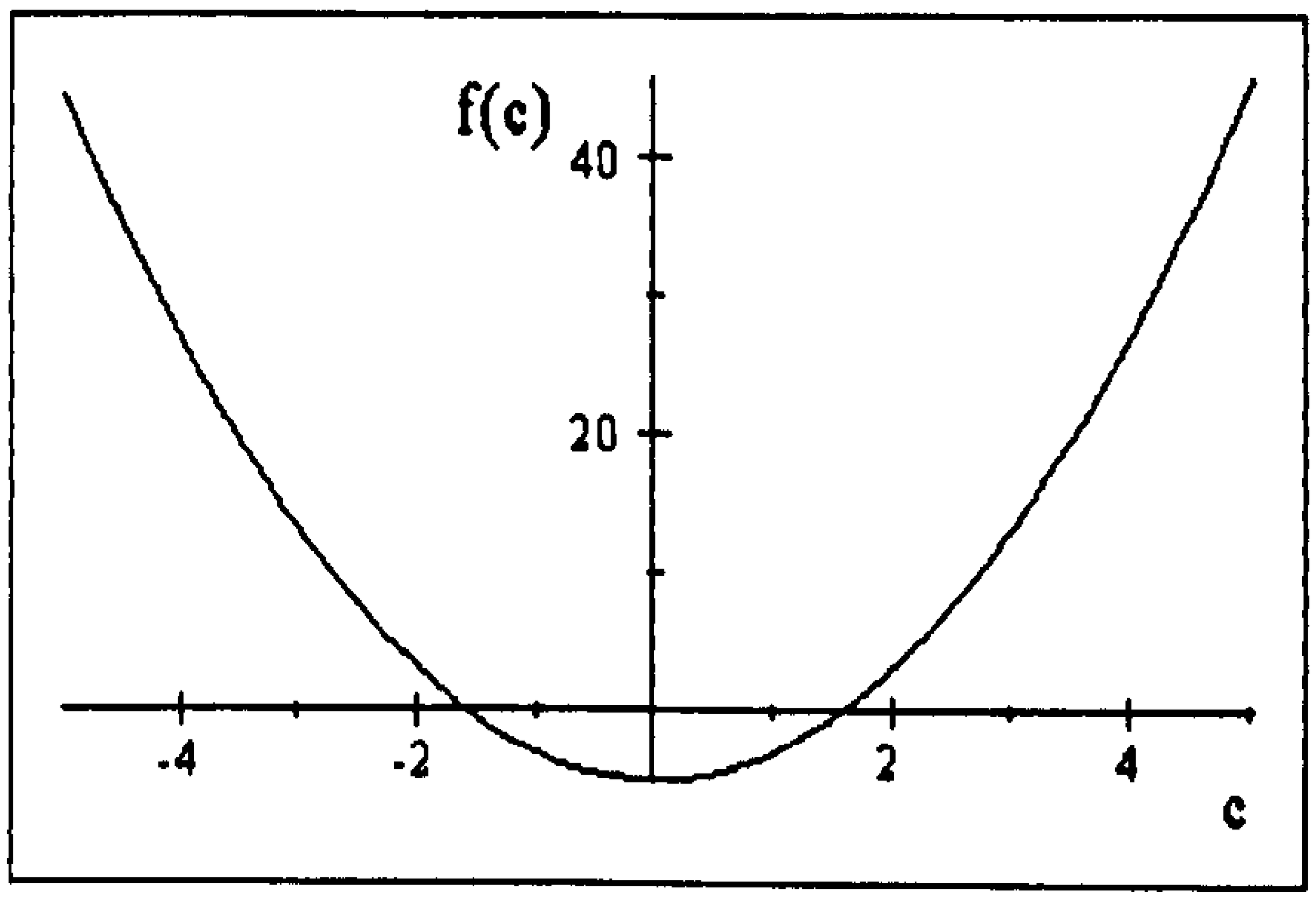
$$
\begin{aligned}
f(c) &= c^2\left(\frac{(p_H-\varepsilon)(p_L-\varepsilon)p_L}{p_H(1-\delta)}-\varepsilon^2\right)+c2\left(\varepsilon p_L+\frac{(p_H-\varepsilon)(p_L-\varepsilon)p_L}{p_H(1-\delta)}-\varepsilon^2\right)\\
&\quad+\frac{(p_H-\varepsilon)(p_L-\varepsilon)p_L}{p_H(1-\delta)}-(p_L-\varepsilon)^2
\end{aligned}
$$

The two roots are given by:

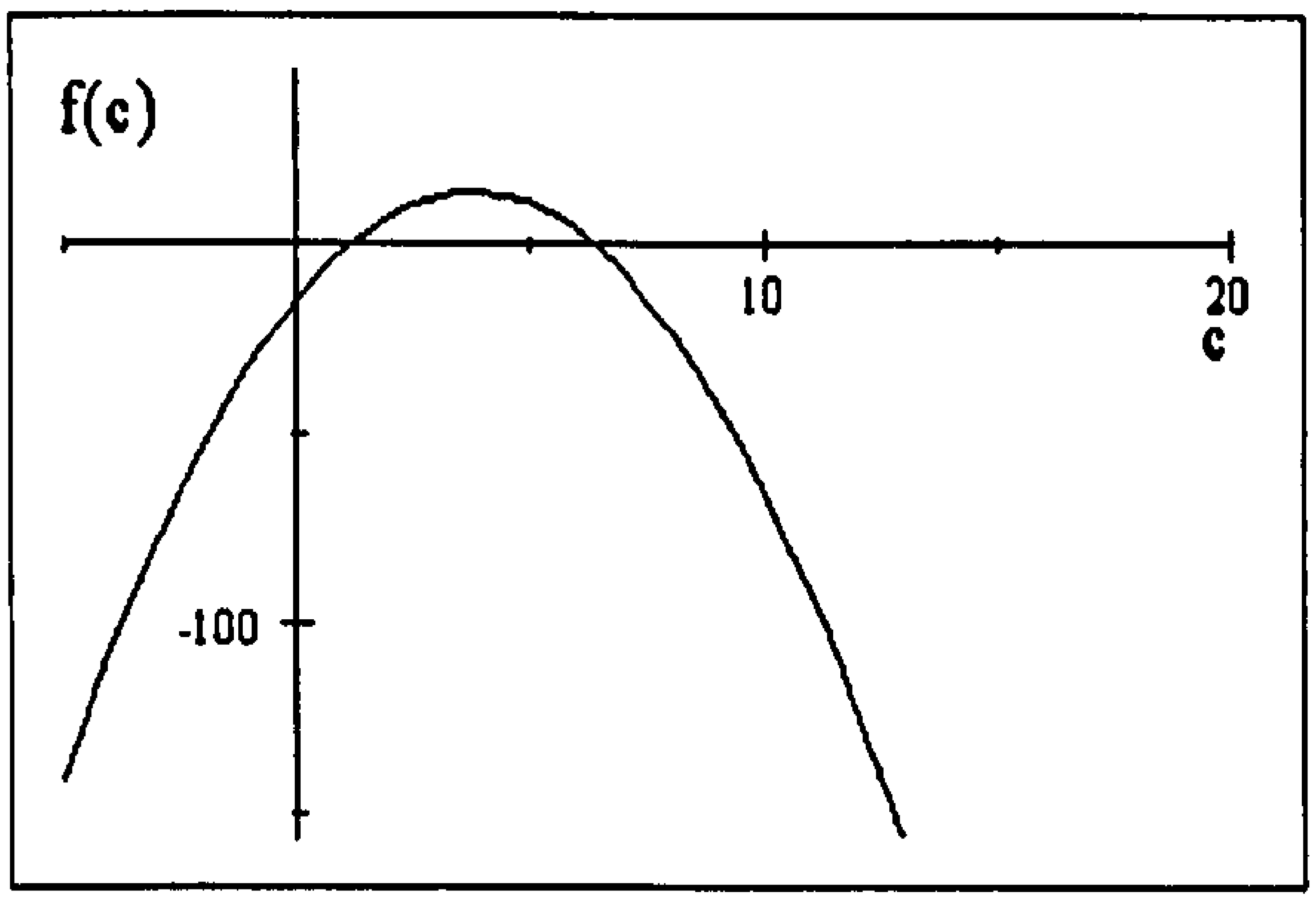
$$
\begin{aligned}
c_1 &= \frac{-\left(\varepsilon p_L+\frac{(p_H-\varepsilon)(p_L-\varepsilon)p_L}{p_H(1-\delta)}-\varepsilon^2\right)-\sqrt{\frac{(p_H-\varepsilon)(p_L-\varepsilon)p_L}{p_H(1-\delta)}p_L^2}}{\left(\frac{(p_H-\varepsilon)(p_L-\varepsilon)p_L}{p_H(1-\delta)}-\varepsilon^2\right)}\\
c_2 &= \frac{-\left(\varepsilon p_L+\frac{(p_H-\varepsilon)(p_L-\varepsilon)p_L}{p_H(1-\delta)}-\varepsilon^2\right)+\sqrt{\frac{(p_H-\varepsilon)(p_L-\varepsilon)p_L}{p_H(1-\delta)}p_L^2}}{\left(\frac{(p_H-\varepsilon)(p_L-\varepsilon)p_L}{p_H(1-\delta)}-\varepsilon^2\right)}
\end{aligned}
$$

Since the coefficient of $c^2$ can take positive or negative values, $f(c)$ can be concave or convex. It follows that , $p_L < 2\varepsilon$ and $\frac{(p_H-\varepsilon)(p_L-\varepsilon)p_L}{p_H(1-\delta)}-\varepsilon^2 < 0$ when $f(c)$ is concave and $p_L > 2\varepsilon$ and $\frac{(p_H-\varepsilon)(p_L-\varepsilon)p_L}{p_H(1-\delta)}-\varepsilon^2 > 0$ when $f(\delta)$ is convex. Moreover, the constant of $f(\delta)$ is negative due to (2.74). Finally, given $c \geq 0$, the following two cases are possible:

Case 1: If e.g. $c_1 < 0 < c_2 < \widetilde{c}$, then $\frac{\partial D}{\partial c}$ is negative when $c \in (0, c_2)$ and positive when $c \in (c_2, \widetilde{c})$.



Case 2: If e.g. $c_2 < \widetilde{c} < c_1$, then $\frac{\partial D}{\partial c}$ is negative when $c \in (0, c_2)$ and positive when $c \in (c_2, \widetilde{c})$.




We now use a numerical example to show that an increase of the screening cost might shift the dynamic path $k_{t+1}^{s1}$ up or down. We use the values $p_L = 0.5, p_H = 0.4, \varepsilon = 0.3, \delta = 0.2$ which satisfy (2.71)and (2.74). The range of the screening cost and the quality of screening as given from (2.71) and (2.74), i.e. the values which $c$ and $\delta^{s1}$ can take in order to satisfy the condition $0 < \pi_{lt}^{s1} < 1$, are $c \in [0, 0.096)$ and $\delta^{s1} \in [0, 0.375)$. For the suggested values it is $p_L < 2\varepsilon$ and $\left(\frac{(p_H-\varepsilon)(p_L-\varepsilon)p_L}{p_H(1-\delta)} - \varepsilon^2\right) < 0$ and thus $f(c)$ is concave. We find that $c_2 = 0.05$ and $c_1 = 3.058$. Thus $\frac{\partial D}{\partial c} < 0$ when $c \in (0, c_1)$ but $\frac{\partial D}{\partial c} > 0$ when $c \in (c_1, \widetilde{c})$.

Case 4: $\left(C_H, C_l^{s2}\right)$

The capital stock at the second period comes from the successful high-risk borrowers $0.5\lambda p_H$ and from the low-risk borrowers who where screened and successful in their investment $0.5(1-\lambda)p_L$. The value of the capital stock in $t+1$ is:

$$\begin{aligned} K_{t+1}^{s2} &= 0.5\lambda p_H Q w_t + 0.5(1-\lambda) p_L Q \frac{w_t}{(1+c)} \\ &= 0.5 Q w_t \left(\lambda p_H + (1-\lambda) p_L \frac{1}{(1+c)}\right) \end{aligned}$$

Thus, the per firm capital stock is

$$k_{t+1}^{s2} = Qw_t \left( \lambda p_H + (1-\lambda) p_L \frac{1}{(1+c)} \right)$$

or after substituting for the equilibrium $w_t = (1-\theta) k_t^{\theta}$:

$$k_{t+1}^{s2} = Q(1-\theta) k_t^{\theta} \left( \lambda p_H + (1-\lambda) p_L \frac{1}{(1+c)} \right) = F k_t^{\theta}$$

where $F = Q(1-\theta)\left(\lambda p_H + (1-\lambda) p_L \frac{1}{(1+c)}\right)$.

### Comparative statics

Since the derivation of the contract terms of $C_l^{s2}$ is based on $\pi_{lt}^{s2} = 1$, $c$ and $\delta^{s2}$ should not be considered independent for the purpose of comparative statics analysis. For a given level of quality of screening, the screening cost has to take a precise value in order to satisfy the requirement that there is no rationing. In other words, we want to calculate the effect of a change in $\delta^{s2}$ on $k_{t+1}^{s2}$, conditional on $c$ satisfying the requirement for $\pi_{lt}^{s2} = 1$ throughout.

The generic form of the dynamic capital of the screening regime for $\pi_{lt}^{s} \in [0,1]$ is:

$$k_{t+1}^{s} = Q\left(\lambda p_H w_t + (1-\lambda) p_L \pi_{lt}^{s} q_{lt}^{s} + (1-\lambda)(1-\pi_{lt}^{s}) \varepsilon q_{lt}^{s}\right) \tag{2.76}$$

Notice that (2.76) is equal to (2.28) for the contract terms of the pair $\left(C_H, C_l^{s2}\right)$, equal to (2.26) for the contract terms of the pair $\left(C_H, C_l^{s1}\right)$ and equal to (2.30) for the contract terms of ($C_H$, Home Technology). If we substitute (2.21), $q_{lt}^{s}$ with $q_{lt}^{s2}$ but $\pi_{lt}^{s}$ with its general form given by (2.70), we obtain a general expression for $k_{t+1}^{s2}$:

$$k_{t+1}^{s2} = Q(1-\theta) k_t^{\theta} \left( \lambda p_H + (1-\lambda) \frac{\left(1 - \frac{\varepsilon}{p_H}\right)(1+c)}{\left(1-\delta^{s2}\right)\left(1 - \frac{(1+c)\varepsilon}{p_L}\right)} \frac{1}{1+c} (p_L - \varepsilon) + (1-\lambda) \varepsilon \frac{1}{1+c} \right) \tag{2.77}$$

Since $\pi_{lt}^{s2} = 1$, we solve for $c$:

$$c = \frac{(1-\delta^{s2})(p_L - \varepsilon) p_H - p_L (p_H - \varepsilon)}{(1-\delta^{s2}) \varepsilon p_H + p_L (p_H - \varepsilon)} \tag{2.78}$$

and substitute (2.78) in (2.77):

$$k_{t+1}^{s2} = Q(1-\theta) k_t^{\theta} \left( \lambda p_H + (1-\lambda) \left( \frac{\varepsilon (p_H - p_L) + (p_L - \delta^{s2} \varepsilon) p_H}{(1-\delta^{s2}) p_H} \right) \right)$$

Thus, the derivative of $k_{t+1}^{s2}$ with respect to $\delta^{s2}$ is:

$$\frac{\partial k_{t+1}^{s2}}{\partial \delta^{s2}} = Q(1-\theta) k_t^{\theta} (1-\lambda) \frac{(p_H - \varepsilon) p_L}{(1-\delta^{s2})^2 p_H} > 0$$

So, we find that as the quality of screening increases, the economy moves to a higher capital accumulation path conditional on the screening cost satisfying the requirement that the no rationing probability is equal to one.

Obviously, if we solve $\pi_{lt}^{s2} = 1$ for $\delta^{s2}$ and substitute in (2.77)we obtain the same expression as (2.28). The derivative of $k_{t+1}^{s2}$ with respect to the screening cost is:

$$\frac{\partial k_{t+1}^{s2}}{\partial c} = -Q(1-\theta) k_t^{\theta} (1-\lambda) p_L \frac{1}{(1+c)^2} < 0$$

The interpretation is similar. As the screening cost increases, the economy moves to a lower capital accumulation path conditional on the quality of screening satisfying the requirement that the no rationing probability is equal to one.

Finally, it is obvious from (2.29) that $\frac{\partial k_{ss}^{s2}}{\partial \delta^{s2}} > 0$ and $\frac{\partial k_{ss}^{s2}}{\partial c} < 0$.

**Case 5:** $(C_H,$ Home Technology$)$

There is no screening contract offered to low risk borrowers. The capital stock at the second period comes from the successful high-risk borrowers $0.5\lambda p_H$ and from the lenders that converted their wages into capital after rationing all low-risk borrowers

$0.5(1-\lambda)$. We assume that the lenders can foresee that for the given $\delta$ there is no $\pi^{s}_{lt}$ that satisfies the constraints of the model and thus no screening takes place. The value of the capital stock in $t+1$ is:

$$\begin{aligned} K^{s3}_{t+1} &= 0.5\lambda p_H Q w_t + 0.5(1-\lambda) Q\varepsilon w_t \\ &= 0.5 Q w_t (\lambda p_H + (1-\lambda)\varepsilon) \end{aligned}$$

Thus, the per firm capital stock is:

$$k^{s3}_{t+1} = Q w_t (\lambda p_H + (1-\lambda)\varepsilon)$$

or after substituting for the equilibrium $w_t = (1-\theta) k^{\theta}_t$:

$$k^{s3}_{t+1} = Q(1-\theta) k^{\theta}_t (\lambda p_H + (1-\lambda)\varepsilon) = G k^{\theta}_t$$

■

**Proof. 9: Proof of Proposition 2.3**

Recall that the incentive compatibility constraint for the high-risk borrower binds in both screening and rationing regimes i.e.

$\pi^{r}_{Ht} p_H (Q\rho_{t+1} - R^{r}_{Ht}) q^{r}_{Ht} = \pi^{r}_{Lt} p_H (Q\rho_{t+1} - R_{Lt}) q^{r}_{Lt}$

$\pi^{r}_{Ht} p_H (Q\rho_{t+1} - R^{r}_{Ht}) q^{r}_{Ht} = \phi \left[\pi^{n}_{Lt} p_H (Q\rho_{t+1} - R^{n}_{Lt}) q^{n}_{Lt}\right]$

Moreover, under both regimes the high risk borrower obtains the same contract (his first-best contract). So, it follows that his expected payoff should be the same in the two regimes:

$\pi^{r}_{Lt} p_H (Q\rho_{t+1} - R^{r}_{Lt}) q^{r}_{Lt} = \phi \left(\pi^{n}_{Lt} p_H (Q\rho_{t+1} - R^{n}_{Lt}) q^{n}_{Lt}\right)$

Substituting the equilibrium values of $\pi^{n}_{Lt}$, $q^{r}_{Lt}$, $q^{n}_{Lt}$, $R^{r}_{Lt}$ and $R^{n}_{Lt}$ we obtain:

$\pi^{r}_{L}\left(1 - \frac{\varepsilon}{p_L}\right) = \phi - \frac{\varepsilon}{p_L}$

Since $p_L > \varepsilon$, we can write $\varepsilon = \kappa p_L$ where $0 < \kappa < 1$. So, the last equality becomes

$$\phi = \pi_L^r + \kappa\left(1 - \pi_L^r\right) \tag{2.79}$$

If we use (2.22) and (2.24) we can show that $k_{t+1}^s > k_{t+1}^r$ when:

$p_L \frac{1+\gamma\phi}{1+\gamma} > p_L \pi_L^r + \left(1 - \pi_L^r\right)\varepsilon$

or since $\varepsilon = \kappa p_L$:

$\frac{1+\gamma\phi}{1+\gamma} > \pi_L^r + \left(1 - \pi_L^r\right)\kappa$

Finally, using (2.79) we obtain:

$\frac{1+\gamma\phi}{1+\gamma} > \phi$ or $1 > \phi$ which is true ■

**Proof. 10: Proof of Proposition 2.4**

If we compare (2.22) to (2.26) and do some algebraic manipulation we find that $k_{t+1}^{s1} > k_{t+1}^r$ when:

$$f(c) = \left(k_{t+1}^{s1} - k_{t+1}^r\right) = c^2 + c\xi + \zeta \tag{2.80}$$

is positive, where

$\xi = \frac{((p_L - \delta^{s1}\varepsilon)p_L(p_H-\varepsilon)(\varepsilon p_H + p_L(p_H-\varepsilon)) - (p_L-\varepsilon)(1-\delta^{s1}))}{\varepsilon(1-\delta^{s1})} \lesseqgtr 0$

$\zeta = \frac{(p_L-\varepsilon)\delta^{s1}p_L(p_H-\varepsilon)(\varepsilon p_H + p_L(p_H-\varepsilon))}{\varepsilon(1-\delta^{s1})} > 0$

The roots of $f(c)$ are:

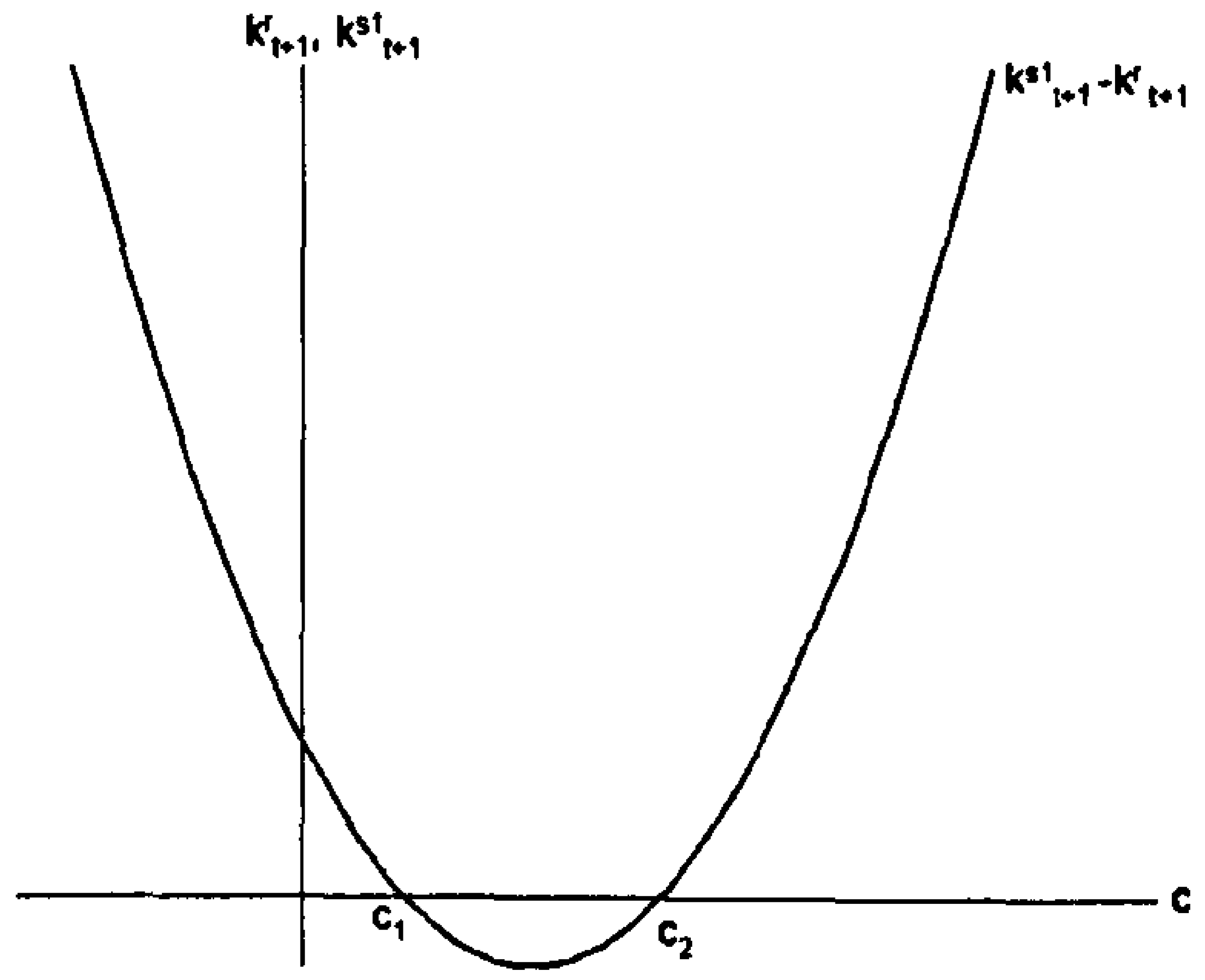
$$c_1 = \frac{-\xi - \sqrt{\xi^2 - 4\zeta}}{2},\ c_2 = \frac{-\xi + \sqrt{\xi^2 - 4\zeta}}{2}$$

Notice that these roots should lie inside the range of possible values of $c$ that satisfy the constraint $0 < \pi_{Lt}^{s1} < 1$ i.e. $c \in [0, \widetilde{c})$.

In order for $c_1$, $c_2$ to exist we need $\xi^2 - 4\zeta > 0$ or

$$\frac{\begin{array}{c}((p_L - \delta^{s1}\varepsilon)\,p_L\,(p_H - \varepsilon)\,(\varepsilon p_H + p_L\,(p_H - \varepsilon)) - (p_L - \varepsilon)\,(1 - \delta^{s1}))^2 \\ -4\,(p_L - \varepsilon)\,\delta^{s1} p_L\,(p_H - \varepsilon)\,(\varepsilon p_H + p_L\,(p_H - \varepsilon))\,\varepsilon\,(1 - \delta^{s1})\end{array}}{(\varepsilon\,(1 - \delta^{s1}))^2} > 0 \tag{2.81}$$

Since $c \geq 0$ and $\zeta > 0$ the only possible scenario is that both roots are positive. The below figure shows that for $c_1 < c < c_2$ it is $k^{s1}_{t+1} < k^{r}_{t+1}$ but for $0 \leq c < c_1$ and $c > c_2$ it is $k^{s1}_{t+1} > k^{r}_{t+1}$.




For $c_1 > 0$ we need $\xi < \sqrt{\xi^2 - 4\zeta}$ which is possible only if $\xi < 0$ or

$$(p_L - \delta^{s_1}\varepsilon)\, p_L\, (p_H - \varepsilon)\, (\varepsilon p_H + p_L\, (p_H - \varepsilon)) - (p_L - \varepsilon)\, (1 - \delta^{s_1}) < 0 \qquad (2.82)$$

So, since in $-\xi > \sqrt{\xi^2 - 4\zeta}$ both sides are positive, raising them at the power of two will not change the direction of the inequality. So:

$(-\xi)^2 > \xi^2 - 4\zeta$

$\Rightarrow 4\zeta > 0$

which holds.

Lastly, $c_2 > 0$ when $\xi < \sqrt{\xi^2 - 4\zeta}$ which is obviously true since $\xi < 0$.

Summarizing, as long as (2.82) holds then both roots are positive. Moreover, we need to make sure that (2.71), (2.74), (2.81)and (2.82) are compatible ($p_L > (1 + c)\,\varepsilon$ is automatically satisfied when (2.71) is satisfied). In what follows we give a numerical example showing that $k^{r}_{t+1}$ can be bigger or smaller than $k^{s1}_{t+1}$ for a set of parameter values.

For $p_L = 0.5$, $p_H = 0.4$, $\varepsilon = 0.3$ and $\delta^{s_1} = 0.2$, (2.71), (2.74), (2.81)and (2.82) are satisfied as well as $\varepsilon < p_H < p_L$. From (2.71) we find that the possible range of values for the screening cost is $c \in [0, 0.096)$. We obtain that $f(c) = c^2 - 0.651\,c + 0.001$ and thus the roots are $c_1 = 0.002$ and $c_2 = 0.649$. So, we find that:

$k^{s1}_{t+1} - k^{r}_{t+1} > 0$ for $0 < c < 0.002$

$k^{s1}_{t+1} - k^{r}_{t+1} < 0$ for $0.002 < c < 0.096$ ■

### Proof. 11: Proof of Proposition 2.5

Recall that the incentive compatibility constraint for the high-risk borrower binds in both screening and rationing regimes i.e.

$\pi^{r}_{Ht} p_H \left(Q\rho_{t+1} - R^{r}_{Ht}\right) q^{r}_{Ht} = \pi^{r}_{Lt} p_H \left(Q\rho_{t+1} - R_{Lt}\right) q^{r}_{Lt}$

$\pi^{r}_{Ht} p_H \left(Q\rho_{t+1} - R^{r}_{Ht}\right) q^{r}_{Ht} = \pi^{s2}_{lt} \left(1 - \delta^{s_2}\right) p_H \left(Q\rho_{t+1} - R^{s2}_{l}\right) q^{s2}_{lt}$

Moreover, under both regimes the high risk borrower obtains the same contract (his first-best contract). So, it follows that his expected payoff should be the same in the two regimes. So, equating the RHS of the two expressions and solve for $\pi^{r}_{Lt}$ we obtain:

$$\pi^{r}_{Lt} = \frac{\left(1 - \delta^{s_2}\right)\left(1 - \frac{(1+c)\varepsilon}{p_L}\right)\frac{1}{(1+c)}}{\left(1 - \frac{\varepsilon}{p_L}\right)} \tag{2.83}$$

If we assume that $k^{s2}_{t+1}$ is bigger than $k^{r}_{t+1}$ then by comparing (2.22) to (2.28) we obtain:

$\frac{p_L}{(1+c)} > (p_L - \varepsilon)\,\pi^{r}_{L} + \varepsilon$

or, by substituting (2.83):

$p_L > \varepsilon\,(1 + c)$

which is true since it is the original definition of developed markets ■

### Proof. 12: Proof of Proposition 2.6

By comparing (2.28) to (2.26) we find that $k^{s2}_{t+1} > k^{s1}_{t+1}$ when $p_L > p_L \pi^{s1}_{lt} + \left(1 - \pi^{s1}_{lt}\right)\varepsilon$ or when $p_L > \varepsilon$ which is always true. ■

**Proof. 13: Proof of Proposition 2.7**

If we assume that $k_{t+1}^{s_3}$ is smaller than $k_{t+1}^{r}$ then by comparing (2.22) to (2.30) we obtain $p_L \pi_L^r + (1 - \pi_L^r)\varepsilon > \varepsilon$ or $(p_L - \varepsilon)\pi_L^r > 0$ which is obviously true ■

**Proof. 14: Comparison of $\beta^{s_1}$ and $\beta^{s_2}$**

Notice that in the following proof we assume that the screening cost $c$ is the same for $C_l^{s_1}$ and $C_l^{s_2}$ but corresponds to different screening quality $\delta^{s_1}$ and $\delta^{s_2}$.

We know that $\beta^{s_1}$ gives the indifference point between $C_l^{s_1}$ and $C_L^r$. So, if we equate the expected payoff for the low risk borrowers from these two contracts and solve for $\beta_L$ we obtain:

$$p_L Q \rho_{t+1} w_t \left(\pi_{lt}^{s_1}\left(1 - \frac{(1+c)\varepsilon}{p_L}\right)\frac{1}{1+c} - \pi_{Lt}^r\left(1 - \frac{\varepsilon}{p_L}\right)\right)\frac{1}{\left(\pi_{lt}^{s_1} - \pi_{Lt}^r\right)} = \beta_L$$

Similarly, $\beta^{s_2}$ gives the indifference point between $C_l^{s_2}$ and $C_L^r$. So, if we equate the expected payoff for the low risk borrowers from these two contracts and solve for $\beta_L$ we obtain:

$$p_L Q \rho_{t+1} w_t \left(\left(1 - \frac{(1+c)\varepsilon}{p_L}\right)\frac{1}{(1+c)} - \pi_{Lt}^r\left(1 - \frac{\varepsilon}{p_L}\right)\right)\frac{1}{\left(1 - \pi_{Lt}^r\right)} = \beta_L$$

Comparing the last two expressions we find that $\beta^{s_1} < \beta^{s_2}$ ■

.

**Proof. 15: Derivation of the equilibrium pairs of contracts**

Case 1: Dynamic paths $s_2$ and $r$

1.1: $\beta_L > \beta_{r_2}^*$

If for a given $k_t$, above inequality holds, then the rationing contract pair $(C_H, C_L^r)$ is the only equilibrium pair at time $t$. To see that this is the unique equilibrium, suppose that lenders are instead offering the pair $\left(C_H, C_l^{s_2}\right)$. From Proposition 2.1 we see that since $\beta_L > \beta_{s_2}^*$ lenders find it optimal to offer the rationing contract and will thus deviate. Therefore, $\left(C_H, C_l^{s_2}\right)$ cannot be an equilibrium.

1.2: $\beta_L < \beta^*_{s_2}$

The lenders offer the pair $\left(C_H, C_l^{s_2}\right)$. To see that this is the unique equilibrium, suppose that lenders are instead offering the pair $(C_H, C_l^r)$. From Proposition 2.1 we see that since $\beta_L < \beta^*_{s_2}$ lenders find it optimal to offer the screening contract and will thus deviate. Therefore, $(C_H, C_l^r)$ cannot be an equilibrium.

1.3: $\beta^*_{r_2} > \beta_L > \beta^*_{s_2}$

If the above relation holds, then there is no pure strategy equilibrium. Lenders randomize between two different contracts. More specifically, the lenders will offer the pair $(C_H, C_L^r)$ with probability $\mu$ since $\beta_L > \beta^*_{s_2}$ and the pair $\left(C_H, C_l^{s_2}\right)$ with probability $(1-\mu)$ since $\beta_L < \beta^*_{r_2}$. In what follows we show that a unique $\mu^* \in (0,1)$ exists that characterizes the unique equilibrium at time $t$ where lenders offer the pair $(C_H, C_L^r)$ with probability $\mu^*$ and the pair $\left(C_H, C_l^{s_2}\right)$ with probability $(1-\mu^*)$. The equilibrium stock of capital will be $k^\mu_{t+1} = \mu^* k^r_{t+1} + (1-\mu^*)\, k^{s_2}_{t+1}$.

We define $\beta^{s_2}_\mu = Q\rho^\mu_{t+1} w_t \left(\frac{1}{(1+c)} + \frac{\varepsilon}{p_H} - \frac{\varepsilon}{p_L} - 1\right) \frac{p_L p_H (p_L-\varepsilon)}{\varepsilon(p_L-p_H)}$ which is the expression for $\beta^{s_2}$ when $\rho_{t+1} = \rho^\mu_{t+1}$ i.e. the marginal product of capital when lenders offer the pair $(C_H, C_L^r)$ with probability $\mu^*$ and the pair $\left(C_H, C_l^{s_2}\right)$ with probability $(1-\mu^*)$. Obviously, $\rho^\mu_{t+1} = \frac{\partial y}{\partial k^\mu_{t+1}} = \frac{\partial \left(k^\mu_{t+1}\right)^\theta L^{1-\theta}_{t+1}}{\partial k^\mu_{t+1}} = \theta \left(k^\mu_{t+1}\right)^{\theta-1} = \theta \left(\mu^* k^r_{t+1} + (1-\mu^*)\, k^{s_2}_{t+1}\right)^{\theta-1}$. Substituting $w_t$ and $\rho^\mu_{t+1}$ we get

$\beta^{s_2}_\mu = Q\theta \left(\mu^* k^r_{t+1} + (1-\mu^*)\, k^{s_2}_{t+1}\right)^{\theta-1} w_t \left(\frac{1}{(1+c)} + \frac{\varepsilon}{p_H} - \frac{\varepsilon}{p_L} - 1\right) \frac{p_L p_H (p_L-\varepsilon)}{\varepsilon(p_L-p_H)}$. Remember that the mixed strategy is an equilibrium strategy if and only if $\beta^*_2 = \beta_\mu$. We see that for $\mu = 1$ we get $\beta_\mu = \beta^*_{r_2}$, for $\mu = 0$ we get $\beta_\mu = \beta^*_{s_2}$ and since $\beta^*_{r_2} > \beta_L > \beta^*_{s_2}$ there exists a unique $\mu^*$ yielding $\beta^{s_2}_\mu = \beta_L$. For this $\mu^*$, the described scenario is an equilibrium outcome in mixed strategies.

Case 2: Dynamic paths $s_1$ and $r$

2.1: $\beta_L > \beta^*_{s_1}$

If for a given $k_t$, above inequality holds, then the rationing contract pair $(C_H, C_L^r)$ is the only equilibrium pair at time $t$. To see that this is the unique equilibrium, suppose that lenders are instead offering the pair $\left(C_H, C_l^{s_1}\right)$. From Proposition 2.1 we see that since $\beta_L > \beta^*_{s_1}$, lenders find it optimal to offer the rationing contract and will thus deviate. Therefore, $\left(C_H, C_l^{s_1}\right)$ cannot be an equilibrium.

2.3: $\beta_L < \beta^*_{r_1}$

If for a given $k_t$, above inequality holds, then the screening contract pair $\left(C_H, C_l^{s_1}\right)$ is offered. To see that this is the unique equilibrium, suppose that lenders are instead offering the pair $(C_H, C_l^r)$. From Proposition 2.1 we see that since $\beta_L < \beta^*_{r_1}$, lenders find it optimal to offer the screening contract and will thus deviate. Therefore, $(C_H, C_l^r)$ cannot be an equilibrium.

2.2: $\beta^*_{r_1} > \beta_L > \beta^*_{s_1}$

If the above relation holds, then there is no pure strategy equilibrium. The lenders will randomize between offering the pair $(C_H, C_L^r)$ with probability $\omega$ since $\beta_L > \beta^*_{s_1}$ and the pair $\left(C_H, C_l^{s_1}\right)$ with probability $(1-\omega)$ since $\beta_L < \beta^*_{r_1}$. Similarly to before, it can be proved that a unique $\omega^* \in (0,1)$ exists that characterizes the unique equilibrium at time $t$ where lenders offer the pair $(C_H, C_L^r)$ with probability $\omega^*$ and the pair $\left(C_H, C_l^{s_1}\right)$ with probability $(1-\omega^*)$. The equilibrium stock of capital will be $k^{\omega}_{t+1} = \omega^* k^r_{t+1} + (1-\omega^*)\, k^{s_1}_{t+1}$.

The cases of section 6.2. can be proved in a similar way. ■

**Proof. 16: Conditions for avoiding a poverty trap when $k^r_{ss} < k^{r_2} < k^{s_2} < k^{s_2}_{ss}$**

We can calculate the derivatives of $k^{r_2}$ with respect to the policy instruments with similar reasoning to Proof 8. If we substitute (2.78) in (2.36), we obtain:

$$k^{r_2} = \beta_L^{\frac{1}{\theta^2}} \left( \left( \frac{(p_H - \varepsilon)}{(1-\delta^{s_2})\, p_H} + \frac{\varepsilon}{p_H} - 1 \right) \frac{p_L p_H \,(p_L - \varepsilon)}{\varepsilon\,(p_L - p_H)} Q\,(1-\theta)\,\theta A^{\theta-1} \right)^{-\frac{1}{\theta^2}}$$

and thus

$$\frac{\partial k^{r_2}}{\partial \delta^{s_2}} = -\frac{1}{\theta^2} \beta_L^{\frac{1}{\theta^2}} \left( \left( \frac{(p_H - \varepsilon)}{(1-\delta^{s_2})\, p_H} + \frac{\varepsilon}{p_H} - 1 \right) \frac{p_L p_H \,(p_L - \varepsilon)}{\varepsilon\,(p_L - p_H)} Q\,(1-\theta)\,\theta A^{\theta-1} \right)^{-\frac{1}{\theta^2}-1}$$
$$\frac{p_L p_H \,(p_L - \varepsilon)}{\varepsilon\,(p_L - p_H)} Q\,(1-\theta)\,\theta A^{\theta-1} \frac{(p_H - \varepsilon)}{(1-\delta^{s_2})^2\, p_H} < 0$$

since $\left( \frac{(p_H - \varepsilon)}{(1-\delta^{s_2})\, p_H} + \frac{\varepsilon}{p_H} - 1 \right) > 0$ or $\delta^{s_2}\,(p_H - \varepsilon) > 0$ which holds.

Finally, we use (2.36) to calculate:

$$\frac{\partial k^{r_2}}{\partial c}=\frac{1}{\theta^2}\beta_L^{\frac{1}{\theta^2}}\left(\left(\frac{1}{(1+c)}+\frac{\varepsilon}{p_H}-\frac{\varepsilon}{p_L}-1\right)\frac{p_Lp_H(p_L-\varepsilon)}{\varepsilon(p_L-p_H)}Q(1-\theta)\theta A^{\theta-1}\right)^{-\frac{1}{\theta^2}-1}$$
$$\frac{p_Lp_H(p_L-\varepsilon)}{\varepsilon(p_L-p_H)}Q(1-\theta)\theta A^{\theta-1}\frac{1}{(1+c)^2}>0$$

since we have assumed that $\beta^{s_2}>\beta_L$ which implies that $\left(\frac{1}{(1+c)}+\frac{\varepsilon}{p_H}-\frac{\varepsilon}{p_L}-1\right)>0$.

Notice that there is no need to substitute for $A$ as it does not depend on the screening cost or the quality of screening. ■

**Proof. 17 : Conditions for avoiding a poverty trap when $k^r_{ss}<k^{r_1}<k^{s_1}<k^{s_1}_{ss}$**

Since $k^{r_1}$ depends on $A$ which does not depend on $\delta, c$, there is no need to substitute for it. Thus, the derivatives of interest are:

$$\frac{\partial k^{r_1}}{\partial c}=\beta_L^{\frac{1}{\theta^2}}\left(Q(1-\theta)\theta A^{\theta-1}\right)^{-\frac{1}{\theta^2}}\left(-\frac{1}{\theta^2}\right)\left(\frac{\delta^{s_1}(p_L-(1+c)\varepsilon)(p_L-\varepsilon)}{c(p_L-\delta^{s_1}\varepsilon)+\delta^{s_1}(p_L-\varepsilon)}\right)^{-\frac{1}{\theta^2}-1}$$
$$\frac{(-\delta^{s_1}\varepsilon(p_L-\varepsilon))(c(p_L-\delta^{s_1}\varepsilon)+\delta^{s_1}(p_L-\varepsilon))-(\delta^{s_1}(p_L-(1+c)\varepsilon)(p_L-\varepsilon))(p_L-\delta^{s_1}\varepsilon)}{(c(p_L-\delta^{s_1}\varepsilon)+\delta^{s_1}(p_L-\varepsilon))^2}>0$$

and

$$\frac{\partial k^{r_1}}{\partial \delta^{s_1}}=\beta_L^{\frac{1}{\theta^2}}\left(Q(1-\theta)\theta A^{\theta-1}\right)^{-\frac{1}{\theta^2}}\left(-\frac{1}{\theta^2}\right)\left(\frac{\delta^{s_1}(p_L-(1+c)\varepsilon)(p_L-\varepsilon)}{c(p_L-\delta^{s_1}\varepsilon)+\delta^{s_1}(p_L-\varepsilon)}\right)^{-\frac{1}{\theta^2}-1}$$
$$\frac{p_Lc(p_L-(1+c)\varepsilon)(p_L-\varepsilon)}{(c(p_L-\delta^{s_1}\varepsilon)+\delta^{s_1}(p_L-\varepsilon))^2}<0$$

■

**Proof. 18 : Conditions for avoiding a poverty trap when $k^{s_1}_{ss} < k^{s_1} < k^{r_1} < k^{r}_{ss}$**

In order to examine the capital dynamics and the effects of changes on $c$ and $\delta^{s_1}$, apart from the restrictions on $c$ and $\delta^{s_1}$ ((2.71) and (2.74)) coming from the condition $0 < \pi^{s_1}_{lt} < 1$, an extra restriction should be taken into to consideration. More specifically, we need to control for the fact that Path $s_1$ lies below Path $r$ i.e. $k^{s_1}_{t+1} < k^{r}_{t+1}$ or (2.80) is negative.

In Proof 8 we show that $\frac{\partial D}{\partial c} \lesseqgtr 0$ and $\frac{\partial D}{\partial \delta^{s_1}} > 0$. Since $k^{s_1}_{ss} = D^{1/(1-\theta)}$ it follows that $\frac{\partial k^{s_1}_{ss}}{\partial c} \lesseqgtr 0$ and $\frac{\partial k^{s_1}_{ss}}{\partial \delta^{s_1}} > 0$. But how does the relevant threshold level of capital change for a given change of the screening cost or the quality of screening? Calculating the derivative of $k^{s_1}$ with respect to $c$ we find that:

$$\begin{aligned}
\frac{\partial k^{s_1}}{\partial c} &= \theta^{-\frac{1}{\theta^2}} \left(Q\left(1-\theta\right)\right)^{-\frac{1}{\theta}} \beta_L^{\frac{1}{\theta^2}} \frac{1}{\theta^2} \left(\lambda p_H + \frac{\left(1-\lambda\right)\left(1-\frac{\varepsilon}{p_H}\right)\left(p_L-\varepsilon\right)}{\left(1-\delta^{s_1}\right)\left(1-\frac{(1+c)\varepsilon}{p_L}\right)} + \frac{\left(1-\lambda\right)\varepsilon}{1+c}\right)^{\frac{1-\theta}{\theta^2}} \\
&\quad \left(\frac{\delta^{s_1}\left(p_L-\left(1+c\right)\varepsilon\right)\left(p_L-\varepsilon\right)}{c\left(p_L-\delta^{s_1}\varepsilon\right)+\delta^{s_1}\left(p_L-\varepsilon\right)}\right)^{-\frac{1}{\theta^2}} \\
&\quad \left\{\frac{p_L\left(p_L-\varepsilon\right)}{\left(c\left(p_L-\delta^{s_1}\varepsilon\right)+\delta^{s_1}\left(p_L-\varepsilon\right)\right)\left(p_L-\left(1+c\right)\varepsilon\right)}\right. \\
&\quad + \left(1-\theta\right)\left(\lambda p_H + \frac{(1-\lambda)\left(1-\frac{\varepsilon}{p_H}\right)(p_L-\varepsilon)}{(1-\delta^{s_1})\frac{p_L-(1+c)\varepsilon}{p_L}} + \frac{(1-\lambda)\varepsilon}{1+c}\right)^{-1} \\
&\quad \left.\left(1-\lambda\right)\varepsilon\left(\frac{\left(1-\frac{\varepsilon}{p_H}\right)(p_L-\varepsilon)p_L}{(1-\delta^{s_1})(p_L-(1+c)\varepsilon)^2} - \frac{1}{(1+c)^2}\right)\right\}
\end{aligned}$$

The first two lines of the above expression are always positive. However, the sign of the last parenthesis is not immediately obvious. We use simulations and taking into consideration the range of values of all the parameters and the constraints outlined above we find that it always takes positive values (see Figure 15). Thus, $\frac{\partial k^{s_1}}{\partial c} > 0$.

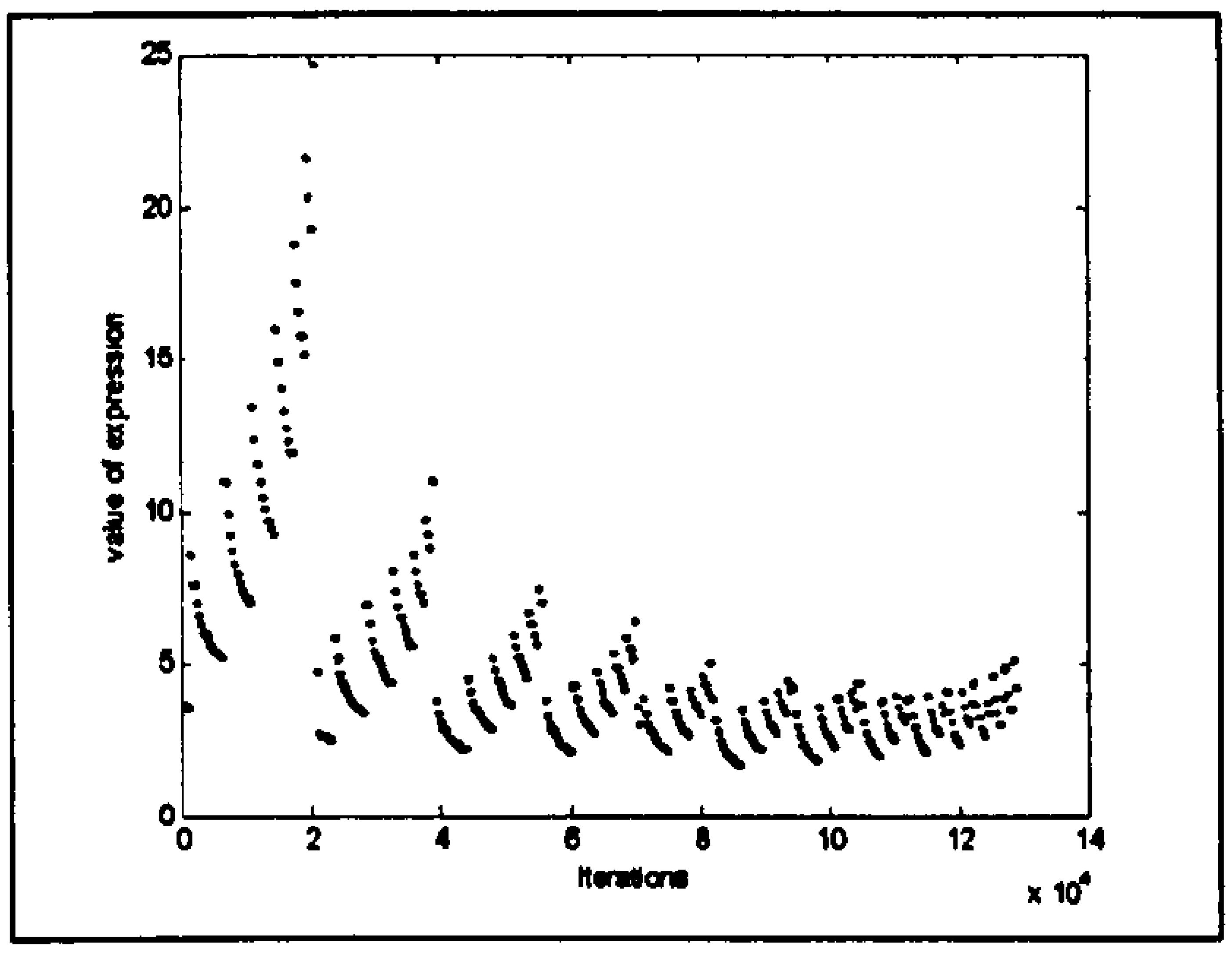
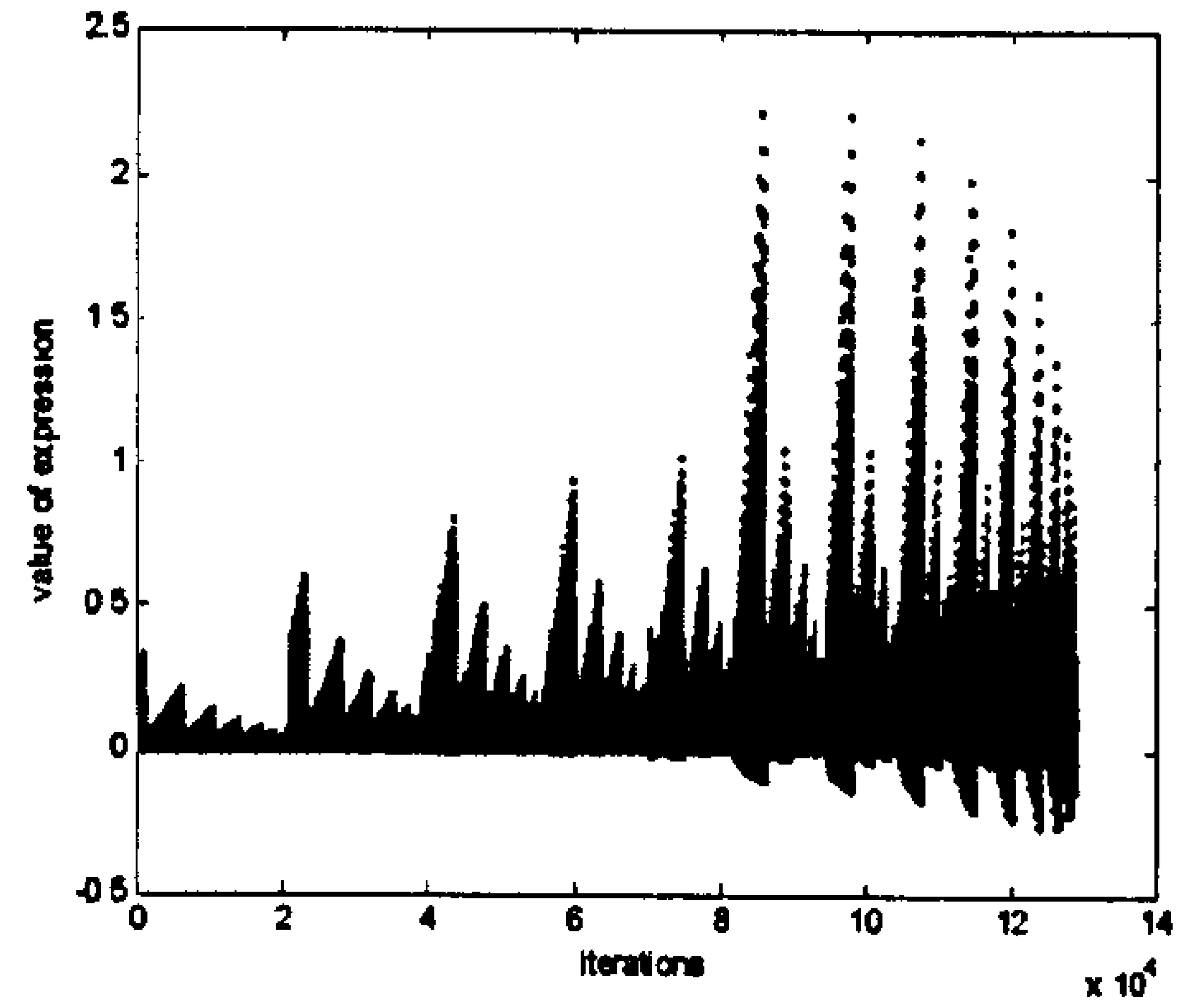



Figure 15

The derivative of $k^{s_1}$ with respect to $\delta^{s_1}$ is:

$$
\begin{aligned}
\frac{\partial k^{s_1}}{\partial \delta^{s_1}} &= \beta_L^{\frac{1}{\theta^2}} \theta^{-\frac{1}{\theta^2}-2} \left(Q\left(1-\theta\right)\right)^{-\frac{1}{\theta}} \\
& \left(\lambda p_H + \frac{\left(p_L - \varepsilon\right)\left(1 - \frac{\varepsilon}{p_H}\right)\left(1-\lambda\right)}{\left(1-\delta^{s_1}\right)\left(1 - \frac{(1+c)\varepsilon}{p_L}\right)} + \frac{\left(1-\lambda\right)\varepsilon}{1+c}\right)^{\frac{1-\theta}{\theta^2}-1} \\
& \left(\frac{\delta^{s_1}\left(p_L - \left(1+c\right)\varepsilon\right)\left(p_L - \varepsilon\right)}{c\left(p_L - \delta^{s_1}\varepsilon\right) + \delta^{s_1}\left(p_L - \varepsilon\right)}\right)^{-\frac{1}{\theta^2}-1} \frac{\left(p_L - \left(1+c\right)\varepsilon\right)\left(p_L - \varepsilon\right)}{c\left(p_L - \delta^{s_1}\varepsilon\right) + \delta^{s_1}\left(p_L - \varepsilon\right)} \\
& \left\{-\frac{c p_L}{\left(c(p_L - \delta^{s_1}\varepsilon) + \delta^{s_1}(p_L - \varepsilon)\right)} \left(\lambda p_H + \frac{(p_L-\varepsilon)\left(1-\frac{\varepsilon}{p_H}\right)(1-\lambda)}{(1-\delta^{s_1})\left(1-\frac{(1+c)\varepsilon}{p_L}\right)} + \frac{(1-\lambda)\varepsilon}{1+c}\right)\right. \\
& \left. + \frac{\delta^{s_1}(1-\theta)(p_L-\varepsilon)\left(1-\frac{\varepsilon}{p_H}\right)(1-\lambda)}{(1-\delta^{s_1})^2\left(1-\frac{(1+c)\varepsilon}{p_L}\right)}\right\}
\end{aligned}
$$

Notice that the first three lines of the above expression are always positive. We use simulations and taking into consideration the range of values of all the parameters and the constraints outlined above we find that the last parenthesis takes both positive and negative values (see Figure 16). Thus, $\frac{\partial k^{s_1}}{\partial \delta^{s_1}} \lesseqgtr 0$.



value of expression
2.5
2
1.5
1
0.5
0
-0.5
0
2
4
6
8
10
12
14
iterations
x 10^4


Figure 16

# Chapter 3

# Financial development, openness and competition in the Euro Area and the US

[1]

## 3.1 Introduction

Various factors have been suggested to influence the degree of competition in different industries across countries. Barriers to entry, product differentiation, the number of firms in a market and the degree of concentration are examples of industry specific determinants of competition. Government subsidies, the strictness and enforcement of competition policy, openness to trade and financial development are some of the potential country specific factors.

Since product market competition is a complex and multi-dimensional process, few broad and aggregate indicators can characterise the degree or intensity of com-

[1] This paper is largely my own work. However, it is part of a bigger project with Rebekka Christopoulou and Philip Vermeulen to who the author of the current paper is highly indebted for providing her with their data.

petition in different markets, and no single indicator can do so. Thus, a broad range of indicators is required, each capturing one element of competition. This paper uses the mark-up of product prices over marginal costs as a measure of a possible manifestation of imperfect competition. A markup ratio bigger than one implies that prices exceed marginal costs and are, thus, evidence of market power in a sector.

The relation of markups to macroeconomic variables is interesting from the standpoint of competition regulators. Policy-makers need to know whether certain policies are conducive to competition and analysts of trade policy and the financial sector need to understand their effects on competition.

This study focuses on the relation between competition and country-specific factors and it is part of the research effort attempting to bring the above predictions to the data. In particular, it investigates the relationship between the degree of competition and the financial environment or trade openness. The empirical estimations are for 50 sectors for 8 Eurozone member states and U.S. over 1981-2004.

We use the Solow residual, a growth accounting methodology which measures the growth rate of productivity, and try to identify the extent at which financial development or trade openness of a country influences competition. Furthermore, we look into whether such a link is stronger for specific industries. More specifically, we investigate the relation between financial depth or the degree of banking liberalization and industry competition. For example, financial depth may be associated with greater ease of entry and thus increased competition. Then, we control for the case of financial depth having a greater effect on competition in sectors where firms are relatively more dependent on external finance, drawing on the central idea of Rajan and Zingales (1998). The relation between trade openness and competition is then investigated. In response to greater foreign competition and increased imports, the market share for domestic producers falls and markups should decline. This relation might be stronger for those industries for which the relative volume of international trade is greater.

The findings of this paper suggest that financial development may have induced lower markups in the Eurozone and US over the period 1981-2004. Moreover, there is evidence that financial depth has a greater effect on competition in sectors where firms are unusually dependent on external finance. These findings are not present across all specifications, nor robust to the different financial development measures or external dependence measures considered. Still, their occasional presence suggests pro-competitive effects. The relation is more potent over the period 1995-2004. Furthermore, there is strong evidence that increased trade openness is linked with higher competition and thus lower markups. This relation appears to be more robust for industries with a higher degree of tradedness.

The rest of the paper proceeds as follows. Section two explains the methodology and the theoretical underpinnings of the various specifications to be estimated. Section three outlines the data. Section four presents and discusses the results. Section five concludes.

## 3.2 Methodology and Theoretical Underpinnings

### 3.2.1 Solow Residual

Growth accounting is central to the attempt of analyzing the fundament determinants of economic growth. It is an empirical methodology for the decomposition of the observed growth of GDP into changes in factor inputs and in production technology. Since it is not possible to measure technological progress directly, it is measured as "residual growth" i.e. as the part of growth of GDP which cannot be accounted for by the growth of the observable inputs. The pioneering work is Solow (1957) who showed that the difference between output growth and the sum of input growth, weighted by the relative contributions of each of the factors to GDP, is equal to technological change. Solow's analysis assumes constant returns to scale, perfect competition and Hicks neutral technological change. It relies on the growth rates of the quantities of inputs and is often called the primal approach.

Hall (1988) shows that by relaxing the assumption of perfect competition, the Solow residual measures the weighted sum of technological change and the growth rate of the output-capital ratio rather than the rate of technological change alone. The weights depend on the markup of price over marginal coast. Thus:

$$\begin{aligned} & \Delta Q_t - \alpha_{Nt}\Delta N_t - \alpha_{Mt}\Delta M_t - (1-\alpha_{Nt}-\alpha_{Mt})\,\Delta K_t \\ = & \left(1-\frac{1}{\mu_t}\right)(\Delta Q_t - \Delta K_t) + \left(\frac{1}{\mu_t}\right)\theta_t \end{aligned} \tag{3.1}$$

where $\Delta Q_t$ is output growth, $\Delta N_t$ is labour input growth, $\Delta M_t$ is intermediate input growth, $\Delta K_t$ is capital input growth, $\alpha_{Nt}$, $\alpha_{Mt}$ are the labour and capital shares in revenue, $\mu_t$ the price-cost markup and $\theta_t$ the rate of technological change.[2] The left hand side of (3.1) is the definition of the traditional Solow residual ($SR_t \equiv \Delta Q_t - \alpha_{Nt}\Delta N_t - \alpha_{Mt}\Delta M_t - (1-\alpha_{Nt}-\alpha_{Mt})\,\Delta K_t$). Notice that in the case of perfect competition, the markup is equal to one and thus the Solow residual is equal to technological change $\theta_t$.

Roeger (1995) uses Hall (1988) to develop a "dual" Solow residual which is computed from growth rates of factors prices, rather than factor quantities. This dual equation is:

$$\begin{aligned} & \Delta p_t - \alpha_{Nt}\Delta w_t - \alpha_{Mt}\Delta m_t - (1-\alpha_{Nt}-\alpha_{Mt})\,\Delta r_t \\ = & \left(1-\frac{1}{\mu_t}\right)(\Delta p_t - \Delta r_t) + \left(\frac{1}{\mu_t}\right)\theta_t \end{aligned} \tag{3.2}$$

where $\Delta p_t$ is the output price change, $\Delta w_t$ is the wage change, $\Delta m_t$ is the intermediate input price change and $\Delta r_t$ is the user cost change. The left hand side is now defined to be the (negative of) price-based Solow residual ($-SRP_t \equiv \Delta p_t - \alpha_{Nt}\Delta w_t - \alpha_{Mt}\Delta m_t - (1-\alpha_{Nt}-\alpha_{Mt})\,\Delta r_t$).

Roeger shows that after subtracting the traditional Solow residual $SR_t$ from the dual Solow residual $SRP_t$, technological growth drops out and the subsequent expression contains only nominal observable variables. Thus adding (3.1)and (3.2) and

[2] A derivation of this equation can be found in Christopoulou and Vermeulen (2008), for example.

rearranging:

$$
\begin{aligned}
& (\Delta p_t + \Delta Q_t) - \alpha_{Nt} (\Delta w_t + \Delta N_t) - \alpha_{Mt} (\Delta m_t + \Delta M_t) \\
& - (1 - \alpha_{Nt} - \alpha_{Mt}) (\Delta r_t + \Delta K_t) \\
= & \left(1 - \frac{1}{\mu_t}\right) ((\Delta p_t + \Delta Q_t) - (\Delta r_t + \Delta K_t))
\end{aligned} \tag{3.3}
$$

where $(\Delta p_t + \Delta Q_t)$ denotes the *nominal* output growth, $(\Delta w_t + \Delta N_t)$ denotes the nominal wage bill, $(\Delta m_t + \Delta M_t)$ denotes the growth in intermediate input costs and $(\Delta r_t + \Delta K_t)$ denotes growth in capital costs. In other words, subtracting the price based Solow residual from the quantity based Solow residual one gets a "nominal" Solow residual which is a function of the markup and the difference between nominal output growth and nominal capital cost growth.

The "nominal" Solow residual can be used to estimate markups by the following simple regression:

$$y_t = \beta x_t + \varepsilon_t \tag{3.4}$$

where $y_t = SR_t - SRP_t = (\Delta p_t + \Delta Q_t) - \alpha_{Nt} (\Delta w_t + \Delta N_t) - \alpha_{Mt} (\Delta m_t + \Delta M_t) - (1 - \alpha_{Nt} - \alpha_{Mt}) (\Delta r_t + \Delta K_t)$, $x_t = (\Delta p_t + \Delta Q_t) - (\Delta r_t + \Delta K_t)$ and $\beta = \left(1 - \frac{1}{\mu}\right)$. Notice that the markup $\mu$ is assumed to be constant over time. A simple OLS regression can be used to derive an estimate of the markup which is simply

$$\mu = \frac{1}{1 - \beta}$$

Whenever there is some degree of monopoly power, the estimated markup should be greater than one i.e. $\beta$ is expected to be positive.

The method by Roeger (1995) has been used in various studies to estimate industry markups. Roeger (1995), Oliveira Martins et al. (1996), Oliveira Martins and Scarpetta (1999) and Badinger (2007a) use industry level data to estimate markups and Konings et al. 2005, Konings and Vandenbussche 2005, Gorg and Warzynski 2006 use firm level data. More important, Christopoulou and Vermeulen (2008) estimate markups for 50 industries in each of the eight Eurozone countries (Italy, Spain, Netherlands, Austria, Germany, Finland, France, Belgium) and the USA for the period 1981-2004. This paper builds on their estimates. In what follows, there is a detailed presentation of the questions addressed.

### 3.2.2 Specification I

There have been numerous studies on the link between financial development and product market competition. The main question of interest is whether financial intermediation or financial depth have any implications for the extent of product market competition. More specifically, one can look into how markups are affected by financial depth or the degree of banking liberalization. For example, financial depth may be associated with greater ease of entry, and hence greater competition.

There is a rich theoretical and empirical literature on financial development and entry and thus competition. From a theoretical standpoint, Lloyd-Ellis and Bernhardt (2000) and Evans and Jovanovic (1989) suggest that credit constraints leads to lower entry of potentially good entrepreneurs compared with wealthier but less talented ones. Similarly, Cabral and Mata (2003) showed that financing constraints can to some extent explain the positive skewness in the size distribution in young cohorts of firms, whom distribution only moves towards the right-hand side as firms age. Hence, as financial markets develop, access to external finance improves thus making younger firms more likely to enter, and therefore contributing the average firm size to be, all else constant, smaller. Cestone and White (2003) presented a model where more credit market competition spurs more product market competition. The empirical literature agrees with the theoretical predictions. Haber (1997) used historical data and showed that Mexico's textile industry started out larger and relatively more competitive compared to Brazil's. However, since Mexico's financial markets remained underdeveloped, the textile industry had less opportunities for entry and ended up smaller and more concentrated than Brazil's, whom liberalized finance. Guiso, Sapienza, and Zingales (2004) find that financial development enhances the probability an individual starts his own business, favors entry, increases competition, and promotes growth of firms in Italy. Similarly, Cetorelli (2004) showed that deregulation in EU banking markets in the early 1990s has resulted in non-financial sectors's markets characterized by lower average firm size and Cetorelli and Strahan (2006) find that more vigorous banking competition in local U.S. banking markets is associated with higher number of firms in operation and with a smaller average firm size. More recently, Aghion et al. (2007) look on the effects of financial development on the entry of new firms in 16 industrialized and emerging economies and find that access to finance matters most for the entry of small firms but has either no effect or a negative effect on entry by large firms.

However, none to our knowledge has used the Solow residual to explore the relation between financial development and competition. In order to control for the impact of the financial environment, the right hand side of the expression for the nominal Solow residual (3.3) is interacted with the measure of financial development. Thus, the regression to be estimated is:

$$SR_t - SRP_t = (\beta_0 + \beta_1 FIN_t)\left((\Delta p_t - \Delta Q_t) - (\Delta r_t + \Delta K_t)\right) + \varepsilon_t \qquad (3.5)$$

where $FIN_t$ is the variable which describes the financial development of the economy. We are interested in whether $\beta_1$ is negative and significantly different from zero so that higher financial development indicates lower markups. Finally, the markup will be:

$$\mu = \frac{1}{1 - (\beta_0 + \beta_1 FIN)}$$

The markup will be equal to one if the industry is competitive and will be greater than one if there is some degree of monopolistic power. Thus, $(\beta_0 + \beta_1 FIN)$ should be positive.

As a robustness check we implement a "two-stage" approach. We use the estimates of markups of Christopoulou and Vermeulen (2008) as the dependent variable and check the explanatory power of financial development. We also control for other country-specific or industry-specific characteristics. We thus estimate the following regression:

$$markup_t = \alpha + \beta FIN_t + \sum \gamma z_t + \varepsilon_t \tag{3.6}$$

where $z_t$ is any variable that describe country-specific or industry-specific characteristics.

### 3.2.3 Specification II

The level of financial development is broadly similar among the developed countries, even more for west European countries and USA. Since the implementation of the Single European Act in 1986, which had as a core element the creation of a single market within the EU, up to the introduction of the Euro on January 1999, the economies of the Euro area have been subject to a gradual deregulation. So, although there have been financial reforms during the sample period 1981-2004 which may possibly give interesting results, the variation of financial depth/ banking liberalization might give results of limited interest or imprecise estimates. So, we will also check whether financial depth is differently important across sectors. The theoretical underpinning of our test is Rajan and Zingales (1998). This paper shows that the industrial sectors which are relatively more in need of external finance develop faster in countries with more developed financial markets. Moreover, the growth in the number of new establishments is significantly higher in industries dependent on external finance when the economy is financially developed. Similarly, Aghion et al. (2007) use harmonized firm-level data for 16 industrialized and emerging economies and find that access to finance matters most for the entry of small firms and in sectors that are more dependent upon external finance.

We use this idea by adjusting it as follows. Financial depth might have a greater effect on competition in sectors where firms are unusually dependent on external finance. In order to capture this idea, (3.3) changes to:

$$
\begin{aligned}
SR_t - SRP_t &= (\beta_0 + \beta_1 FIN_t + \beta_2 EXDEP + \beta_3 FIN_t * EXDEP) \\
&\quad ((\Delta p_t - \Delta Q_t) - (\Delta r_t + \Delta K_t)) + \varepsilon_t \qquad (3.7)
\end{aligned}
$$

where $EXDEP$ is the variable which describes the external financial dependence of an industry. The financial development variable is interacted with each industry's dependence on external finance and the constitutive terms of the interaction term are also included separately. Of course, the three variables are interacted with $x_t$. We are interested in whether $\beta_1$ and $\beta_3$ are negative and significantly different from zero and whether the derivative of the markup with respect to financial depth is negative. The markup is now given by:

$$\mu = \frac{1}{1 - (\beta_0 + \beta_1 FIN_t + \beta_2 EXDEP + \beta_3 FIN_t * EXDEP)}$$

and the derivative of the markup with respect to $FIN$ is:

$$\frac{\partial markup}{\partial FIN} = \frac{\beta_1 + \beta_3 EXTDEP_i}{(1 - (\beta_0 + \beta_1 FIN_t + \beta_2 EXDEP + \beta_3 FIN_t * EXDEP))^2}$$

Similarly to before, a robustness check via a "two-stage" approach will also be carried out.

### 3.2.4 Specification III

The next question this paper looks into is whether the trade openness of a country has an impact on the extent of competition within various industries. In response to exposure to international competition and increased imports, the market share for domestic producers falls and markups should decline. Empirical studies have found that the link is validated by data. Levinsohn (1993), Harrison (1994) and Hoekman et al. (2004) are all studies that find support for the hypothesis that imports are a source of discipline on domestic firm pricing behavior. Badinger (2007b) finds that trade (import penetration) has pro-competitive effects. Chen, Imbs and Scott (2009) using disaggregated data for EU manufacturing over the period 1989–1999 found short run evidence that trade openness exerts a competitive effect although the long run effects are more ambiguous. Harrison et al. (2006) find that the different product market reforms carried out by the European Union under the Single Market Program, a large project by the then members of the European Union to reduce internal non-tariff barriers to trade and other barriers to the free movement and factors of production across borders, have increased competition as reflected by a reduction in markups. Similarly, Badinger (2007a) suggests that the EU's Single Market Programme led to mark-up reductions for aggregate manufacturing and also for construction although mark-ups have gone up in most service industries since the early 1990s.

The openness of all the countries of our sample has increased over the period of interest. For the Eurozone member states this trend is naturally enhanced by the introduction of the Euro, which resulted in an increased volume of internal trade, a prerequisite as much as a positive outcome of a common currency area. And although one would expect that the common trade policies adopted by the members of EU would not allow for differences in their openness, the data show that the level of openness differs substantially across Euro area countries. So, for the European countries in the sample, Spain exhibits the minimum openness (averaged over time) in the sample (0.37) whereas the maximum openness is found for Belgium (1.23). USA is the least open country of the sample (0.18), where openness is measured by the ratio of exports plus imports to GDP.

To control for the effect of trade openness on product market competition a similar approach to Specification I can be used:

$$SR_t - SRP_t = (\beta_0 + \beta_1 OPEN_t)\left((\Delta p_t - \Delta Q_t) - (\Delta r_t + \Delta K_t)\right) + \varepsilon_t \tag{3.8}$$

where $OPEN$ is the variable which measures the trade openness of an economy. We are interested in whether $\beta_1$ is negative and significantly different from zero, so that higher openness is consistent with lower markups. In this case the markup will be

$$\mu = \frac{1}{1-(\beta_0+\beta_1 OPEN)}$$

We will also control whether financial depth has greater explanatory power on competition in these industries which have high relative volume of international trade. Finally, a robustness check via a "two stage" approach will also be carried out.

### 3.2.5 Specification IV

Rajan and Zingales (2003) showed that trade openness is correlated with financial market development. Hence, the natural last step is to control simultaneously for the impact of the financial development and trade openness on competition. The regression used is:

$$SR_t - SRP_t = (\beta_0 + \beta_1 FIN_t + \beta_2 OPEN_t)\left((\Delta p_t - \Delta Q_t) - (\Delta r_t + \Delta K_t)\right) + \varepsilon_t \quad (3.9)$$

The markup is given by:

$$\mu = \frac{1}{1-(\beta_0+\beta_1 FIN+\beta_2 OPEN)}$$

## 3.3 Data and summary statistics

Our paper draws heavily on the estimations in Christopoulou and Vermeulen (2008). The sample consists of data on 50 industries in each of the eight Eurozone countries (Italy, Spain, Netherlands, Austria, Germany, Finland, France, Belgium) and the USA for the period 1981-2004. Thus, the data have three dimensions i.e. time, industry and country. Data availability does not allow the inclusion of the remaining Eurozone members of the time.[3]

### 3.3.1 Data on industries

The data on the left and right hand side of the "nominal" Solow residual, $y$ and $x$ respectively, as well as the estimates of markups used in the "two-stage" approach are from Christopoulou and Vermeulen (2008). For the calculations they use the EU KLEMS data base (March 2007 Release) apart from the user cost of capital for which data are from the AMECO database. The output and input data are at the two digit level (NACE, Rev. 1.1). More details are provided in their paper.

For the tradability of different industries various measures have been suggested. We follow the approach of De Gregorio, Giovannini and Wolf (1994) which defines an industry as "tradable" if more than 10 percent of total production is exported. They use data for 14 OECD countries over 1970-1985 and find that agriculture, mining, manufacturing and transportation are "tradable" whereas services other than transportation are "nontradable".

### 3.3.2 Data on Countries

Data on Gross Domestic Product are obtained from the OECD (in constant prices and PPP's).

To measure openness we use the ratio of nominal exports plus imports to nominal GDP, using data in current US dollars from the World Development Indicators (June 2009).

[3] According to Christopoulou and Vermeulen (2008), the included countries account for over 90% of the 12 member states output of the time.

### 3.3.3 Measures of Financial Development

We use the following financial measures:

*Liquid liabilities relative to GDP (llgdp):* This equals currency plus demand and interest-bearing liabilities of banks and other financial intermediaries divided by GDP. It is a measure of absolute size based on liabilities and is often used to measure financial depth (see e.g. King and Levine (1993) in their seminal paper on finance and growth or Levine, Loayza and Beck (2000)).

*Private credit by deposit money banks relative to GDP (prib):* This equals claims on the private sector by deposit money banks, divided by GDP. It is a measure of one of the main activities of deposit money banks: the channeling of savings to investors. This measure isolates credit issued to the private sector as opposed to credit issued to governments and public enterprises. Furthermore, it excludes credit issued by the central bank. This indicator has been used by Levine and Zervos (1998), among others.

*Private credit by deposit money banks and other financial institutions relative to GDP (pribof):* This equals claims on the private sector by deposit money banks and other financial institutions, divided by GDP. Similar to *prib*, it is a measure of activity of financial intermediaries and isolates credit issued to the private sector. This indicator has been used by Levine, Loayza and Beck (2000). Data for the above three measures are from Beck, Demirguc-Kunt and Levine (2000).

*Financial freedom (bankfreed)*: This is a measure of banking security as well as a measure of banks' independence from government control. It is a composite index of the extent of government regulation of financial services, the extent of state intervention in banks and other financial services, the difficulty of opening and operating financial services firms and government influence on the allocation of credit. The authors determine the financial climate and assign an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. Data are available from the Heritage Foundation for only a subperiod, namely 1995-2004. We expect this measure to have higher explanatory power compared to the other three since it focuses on the banking industry. The banking industry is the core and most important component in the non Anglo-Saxon financial systems. Although EU member states have adopted Banking Directives[4], which compel them to harmonize their banking sectors, the implementation dates vary across countries (see e.g. Romero-Avila, 2007).

### 3.3.4 Measures of External Dependence

Data on the actual use of external financing of different industries, either across countries or over time, are rarely available. Various proxies have been suggested in the literature for the dependence of industries on security markets, banks and investments by other stakeholders.

*extdepR_Z:* This is the pioneering measure of the dependence on external finance introduced in Rajan and Zingales (1998). It is defined as capital expenditures minus cash flow from operations divided by capital expenditures and is based on data from U.S. firms. The authors argue that since capital markets in the U.S. are among the most advanced in the world, the frictions in accessing external finance are minimal. Thus, the amount of external finance used by large firms is likely to be a good measure of their actual demand for external finance rather than just an equilibrium between the demand and (rationed) supply of such funds. They believe that the dependence of US firms is a good proxy for dependence in other countries, since differences in the degree of dependence of the various industries are due to technological reasons which apply across countries. Data are averaged over the 1980s and are confined to manufacturing industries. The Appendix provides more details.

*extdepM_G:* Maudos and Fernandez de Guevara (2007) suggest the following proxy for dependence:

[4]Directives have the character of binding laws and require EU member states to achieve a particular result without dictating the means of achieving that result, as opposed to EU regulations which are self-executing.

$$\frac{\text{(non current liabilities)+(current liabilities: loans)}}{\text{(total assets)-(current liabilities:creditors)-(other current liabilities)}}$$

Data are averages over 1993-2003 and cover 48 of the 50 industries in our sample. The benchmark country is the United Kingdom on similar reasoning as for the use of U.S.A. for Rajan and Zingales (1998). Moreover, they find that the degree of financial development of U.K. is closer to that of the USA than to the average of the EU-15 and thus is a good proxy for dependence in the countries in the sample for the reasons outlined for the Rajan-Zingales measure. The Appendix provides more details. One can claim that the Maudos-Fernandez de Guevara measure is not a measure of external financial dependence but a measure of dependence to the credit markets as external equity finance (new equity issues) is not taken into account. Inklaar and Koetter (2008) also suggest the use of debt in total assets as a measure of financial dependence.

*Bank Dependence (bankdep):* This measure tries to isolate the dependence of industries on banks rather than other intermediaries. Carlin and Mayer (2003) suggest the use of the proportion of net physical investment financed by bank loans. They provide estimates for 16 of the industries in our sample. Japan is the benchmark country and data are averages for the years 1981-1990. The argument is similar to the "minimal frictions in raising external finance" argument used by the above two papers, in the sense that Japan has one of the highest bank credit to GDP ratios and an unusually high level of bank financing of industry (see e.g. Corbett and Jenkinson, 1997). We expect this measure to have higher explanatory power compared to the other two for reasons similar to the ones explained in the case of *bankfreed.*

### 3.3.5 Descriptive Statistics

Table A presents the descriptive statistics. A special note should be made for the data on markups. Real Estate Activities (sector 70) is an outllier. The markup ratio for the whole period is 9.2 in Italy and around 3 in the rest countries. Christopoulou and Vermeulen (2008) attribute this to possible statistical specificities leading to large measurement errors which imply upward bias of the markup. Their paper provides detail.

Table A

| Variable | Obs | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|
| y | 10213 | 0 00 | 0.05 | -0 84 | 0 80 |
| x | 10290 | -0 02 | 0.17 | -1.66 | 1 79 |
| markup | 447 | 1.35 | 0.55 | 0.94 | 9 20 |
| markup 93-04 | 447 | 1.37 | 0 53 | 0 89 | 8 62 |
| gdp | 216 | 1514463 | 2325521 | 81925 | 10600000 |
| openness | 216 | 0.67 | 0 37 | 0.17 | 1.66 |
| llgdp | 206 | 0.70 | 0.19 | 0.41 | 1.74 |
| prib | 206 | 0 75 | 0.28 | 0.26 | 2 18 |
| pribof | 208 | 0 89 | 0 43 | 0 26 | 3.45 |
| bankfreed | 87 | 67 47 | 13.91 | 50 00 | 90 00 |
| extdepM_G | 48 | 0 43 | 0 11 | 0 16 | 0 71 |
| extdepR_Z | 22 | 0.36 | 0.39 | -0 45 | 1 06 |
| bankdep | 16 | 0.42 | 1.14 | -3 41 | 1 78 |

Note: A description of the data is given in the main text.

The cross correlation coefficients of the variables which vary across countries and time but not across industries are given in Table B. An interesting result is the negative and statistically significant correlation between GDP and trade openness. The result is driven by the U.S. More specifically, the U.S. is a relatively closed economy and has higher level of GDP compared to the other countries of the sample. The explanation is similar for the negative correlation between GDP and financial development when the later is measured by *llgdp* and *prib*. The correlation among the three measures of financial development (*llgdp*, *prib*, *pribof*) is high and statistically significant. However, the correlation between each of these measures and the measure of banking freedom *(bankfreed)* is lower although still statistically significant.

| Table B | | | | | | |
|---|---|---|---|---|---|---|
| | gdp | openness | llgdp | prib | pribof | bankfreed |
| gdp | 1 | | | | | |
| openness | -0.52* | 1 | | | | |
| llgdp | -0.04 | 0.26* | 1 | | | |
| prib | -0.24* | 0.15* | 0.80* | 1 | | |
| pribof | 0.39 | 0.00 | 0.76* | 0.67* | 1 | |
| bankfreed | 0.19 | 0.29* | 0.38* | 0.28* | 0.53* | 1 |

Note: A desrciption of the data is given in the main text.

Table C presents the correlation coefficients of the different measures of external dependence i..e those variables which vary only across industries. The correlation is low and insignificant in all cases. This might be due to the different industries for which data are available for each of the three measures (see appendix for details).

| Table C | | | |
|---|---|---|---|
| | extdepR_Z | extdepM_G | bankdep |
| extdepR_Z | 1 | | |
| extdepM_G | -0.28 | 1 | |
| bankdep | 0.01 | -0.12 | 1 |

Note: A desrciption of the data is given in the main text.

## 3.4 Results

### 3.4.1 Specification I: Financial Development and Competition

#### Results from industry-country specific estimations

Equation (3.5) is estimated for 50 industries in the 8 Eurozone member states and the USA for the period 1981-2004. So, we estimate the following cross-sectional equation for 450 industries:

$$y_t = \beta_0 x_t + \beta_1 x_t FIN_t + \varepsilon_t \tag{3.10}$$

where $t = 1981, 1982, ..., 2004$. The significance of financial development for competition, for the different measures used for $FIN$, is modest in these 450 regressions. The estimated coefficient $\beta_1$ is significant for 91, 97 and 106 of the regressions for *llgdp*, *prib* and *pribof* respectively at the 10% significance level.[5] This is more than would be expected by chance, but it is clear that a null of zero cannot be rejected in the majority of cases.

### Estimations at industry level

It may be reasonable to assume that industries have the same characteristics across different countries. Thus, markups are homogeneous across countries. In that case we are treating the parameters as the same across countries and thus pool the data over time. So, (3.5) can be estimated by industry. The estimation model is:

$$y_{tk} = \beta_0 x_{tk} + \beta_1 x_{tk} FIN_{tk} + \varepsilon_{tk} \tag{3.11}$$

where $k$ is the country index. Equation (3.11) is estimated for 50 industries and for the four measures of financial depth. Heteroskedasticity-robust standard errors are used. The errors might be correlated within groups and so we also cluster by country. Clustering does not affect the point estimates but only modifies the variance-covariance matrix. If the within-cluster correlations are meaningful, ignoring them leads to inconsistent estimates of the variance-covariance matrix. Table 1 shows the results. The estimated coefficient $\beta_1$ often has the "correct sign" but is only significant for 12, 0, 3 and 7 sectors for *llgdp*, *prib*, *pribof* and *bankfreed* respectively (10% significance level). If within-cluster correlations are assumed to be negligible,

[5] The measure *bankfreed* is not used due to the small number of observations (each regression would have only ten observations in this case).

financial development appears significant for more industries but the evidence is still weak.

Hylleberg and Jorgensen (1998) have argued that if the markups are not constant over the period of estimation then a constant term should be added to the regression. We now take this a step further and allow for different intercepts across time and across country. Hence, time and country dummy variables are included as additional explanatory variables. The data set is a panel and the fixed effects model is:

$$y_{tk} = \beta_0 x_{tk} + \beta_1 x_{tk} FIN_{tk} + D_t + D_k + \varepsilon_{ik} \tag{3.12}$$

where $D_t$ are 24 dummy variables (10 when *bankfreed* is used) indicating the year and $D_k$ are 9 dummy variables indicating the country. Table 2 shows that the significance of $FIN$ is slightly higher. More specifically, the estimated coefficient $\beta_1$ often has the "correct" sign but is significant for only 13, 3, 2 and 6 sectors for *llgdp*, *prib*, *pribof* and *bankfreed* respectively (10% significance level). Similar to before, no clustering implies greater significance.

Finally, we can also allow for differences in slopes across countries. In that case $x_{tk}$ is interacted with $D_k$ and the fixed effects model is:

$$y_{tk} = \beta_1 x_{tk} FIN_{tk} + D_t + D_k + \beta_2 x_{tk} D_k + \varepsilon_{ik} \tag{3.13}$$

Notice we drop $x_{tk}$ since this term is collinear with $x_{tk}D_k$. Table 3 shows that the significance of $FIN$ is low even though $\beta_1$ often has the "correct" sign. Financial depth is significant for for 4, 6, 9 and 14 industries for *llgdp*, *prib*, *pribof* and *bankfreed* respectively (10% significance level). No clustering implies greater significance.

No particular industries are repeatedly found to exhibit a sensitive relationship between competition and financial development across the three models of the section and the four measures of financial development. However, there is a looser kind of consistency; Across the three specifications: Electricity and Gas (sector 40) when $FIN$ is measured by *llgdp* (5% significance level), Sewage and refuse disposal, etc (sector 90) when $FIN$ is measured by *bankfreed* (10% significance level) and across the four measures of $FIN$: Activities related to financial intermediation (sector 67) for the third model (10% significance level).

**Robustness test via a "two-stage" approach**

A further way to check the robustness of the results is to use a two-stage approach. Christopoulou and Vermeulen (2008) have estimated markups for the current sample. We use their estimates as the dependent variable and control for the extent of financial development. The logarithm of GDP is used as an additional explanatory variable to capture country specific characteristics. The intercepts are allowed to differ across sectors but not across countries (country dummies would be collinear with both $FIN$ and $GDP$) and thus industry dummies ($D_i$) are included. The data on $FIN$ and $GDP$ are averaged over time since markups are also constant over time, by construction. In the case of *bankfreed* we assume that the markup of the period 1981-2004 is a proxy for the markup of the period 1995-2004.[6] Since, data now vary across industry and country but not over time the data set is cross-sectional and the estimation model is:

$$markup_{ik} = D_i + \beta_1 FIN_k + \beta_2 \ln GDP_k + \varepsilon_{ik} \tag{3.14}$$

where $i$ is the industry identifier. Heteroskedasticity-robust standard errors are used. Table 4 shows that the findings of the above specifications are reproduced by this model. Financial development has only weak explanatory power for the extent of competition, unless it is assumed that the within-cluster correlations are negligible, in which case higher financial development implies lower markups.

Summarizing the findings of Specification I, financial development appears to promote competition but the estimates of this effect are often imprecise. The evidence

[6]Such an assumption is not unreasonable. Christopoulou and Vermeulen (2008) have found that there is no systematic change in markups from 1981-1992 to 1993-2004. A robustness check is carried out later on by repeating the estimation using the markup of 1993-2004.

is relatively stronger if the within-cluster correlations are assumed to be negligible. Among the four measures, *bankfreed* has higher explanatory power, which matches prior expectations given the particular sample.

### 3.4.2 Specification II: Financial Dependence and Competition

#### Results from pooled and panel data estimations

The data for the three measures of dependence on external finance are obtained from a country-benchmark. Some country-specific characteristics relating to financial markets shall indicate whether the external dependence observed is the best possible proxy for the demand for external funds in other countries. So, the first two measures of financial dependence use the USA or the UK as the benchmark country, as these economies are among the most financially advanced and frictions in accessing funds should be minimal. On the other hand, the Carlin-Mayer measure of dependence on banking finance uses Japan since it has the highest ratio of bank credit to GDP and an unusually high level of bank financing of industry.

The data on external dependence is industry-specific and time-invariant. The estimation of the varying effect of financial depth-amended Solow residual per industry per country or per industry is impossible (the two variables relating to the external dependence, $EXDEP$ and $x_tFIN_t * EXDEP$, cannot be included since the former is constant and the later is collinear with $x_tFIN_t$).

One approach to check whether financial depth has a greater effect on competition in sectors where firms are unusually dependent on external finance would be to assume that markups are constant across industries and thus estimate (3.7) per country. However, such an assumption is not very intuitive. An alternative approach is to treat the parameters as the same across units and pool the data of all countries and industries. Table 5 shows the results of the estimation. Financial development and the interaction with external dependence are never significant and the null of joint insignificance cannot be rejected for any combination of the different measures. The explanatory power of financial development is not much stronger either if within-cluster errors are assumed to be uncorrelated, apart from the case when the measure of financial depth is *bankfreed* and the Maudos-Fernandez de Guevara measure of external finance is used.

If the intercepts and slopes for the various industries and countries are allowed to differ we find the following three specifications of particular interest.

$$\begin{aligned} y_{tik} &= D_k + D_i + D_t + x_{tik}D_k + x_{tik}D_i \\ &+\beta_1 x_{tik}FIN_{kt} + \beta_2 x_{tik}FIN_{kt} * EXDEP_i + \varepsilon_{tik} \end{aligned} \tag{3.15}$$

$$\begin{aligned} y_{tik} &= D_k + D_iD_t + x_{tik}D_k + x_{tik}D_i \\ &+\beta_1 x_{tik}FIN_{kt} + \beta_2 x_{tik}FIN_{kt} * EXDEP_i + \varepsilon_{tik} \end{aligned} \tag{3.16}$$

$$\begin{aligned} y_{tik} &= D_i + D_kD_t + x_{tik}D_k + x_{tik}D_i \\ &+ \beta_1 x_{tik}FIN_{kt} + \beta_2 x_{tik}FIN_{kt} * EXDEP_i + \varepsilon_{tik} \end{aligned} \tag{3.17}$$

Notice that the inclusion of country or industry dummies transforms the data set to panel and the equations (3.15), (3.16) and (3.17)are fixed effects models. The component $x_{tik}EXDEP_i$ cannot be included in these specifications as this term will be collinear with $x_{tik}D_i$. The number of industry dummies $D_i$ reflects the number of industries for which data on each of the three measures of external dependence are available and the number of time dummies $D_t$ reflects the number of years that each of the three measures of financial development cover. These three specifications are estimated using heteroskedasticity-robust standard errors and within or without within-cluster correlations. However, it is now more sensible to assume that the cluster is each industry in each country rather than a country. Thus, there are now 450 clusters instead of 9 and the blocks with the nonzero elements on the diagonal of the block-diagonal variance-covariance matrix are "smaller".

The results for regression (3.15) are shown in Tables 6i-6iii, for regression (3.16) are shown in Tables 6iv-6vi and for regression (3.17) are shown in Tables 6vii-6ix. To summarize the findings, we see that models (3.15) and (3.16) provide evidence that financial depth has a greater effect on competition in sectors where firms are relatively more dependent on external finance only if $FIN$ is measured by *bank-freed*.[7] However, specification (3.17) gives more interesting results. When external dependence ($EXDEP$) is measured by *bankdep*, our hypothesis is verified for all four measures of financial development ($FIN$). This result is robust to clustering by industry-country.

### A "two-stage" approach

The hypothesis that financial depth has a greater effect on competition in sectors where firms are unusually dependent on external finance can also be tested by a "two-stage approach", similar to the one we used in the previous section. The dependent variable is the markup and the explanatory variables are the interaction term between financial development and external dependence, the constitutive terms of the interaction term and, of course, GDP. However, similar to Specification I, industry dummies are also included in order to capture industry characteristics and thus $EXTDEP$ drops out. The data on $FIN$ and $lnGDP$ are averages over time. Thus, data is transformed into cross-sectional since there is only industry and country variation but no time variation. So, the model to be estimated is:

$$markup_{ik} = D_i + \beta_1 FIN_k * EXTDEP_i + \beta_2 \ln GDP_k + \beta_3 FIN_k + \varepsilon_{ik} \qquad (3.18)$$

Table 7 gives the results with or without clustering. The estimates of $\beta_1$ or $\beta_2$ are significant when the Rajan-Zingales measure of external finance is used. This

[7] We have tested the regressions (3.15), (3.16) and (3.17) for the joint insignificance of the country dummies or the industry dummies in the case without clustering by industry-country. The null that the industry dummies have zero coefficients cannot be rejected for specification (3.15). Estimating the model without them does not change the results.

result is robust whether we cluster or not by country but not when external finance is measured by *extdepM_ G* or *bankdep*.

Table 8 shows the calculations for the derivative $\frac{\partial markup}{\partial FIN}$ for the four measures of financial depth. Industries are ranked according to *extdepR_ Z* . It is apparent that the higher the external dependence, the higher (in absolute terms) the impact on the markup. Specifically, the hypothesis that greater financial depth is associated with greater competition is verified for the industries with high external dependence when *llgdp* and *pribof* are used, though the derivative is positive for the industries with low dependence. The derivative is negative for all industries with positive external dependence when *prib* is used and close to zero when *bankfreed* is used.The interaction term is significant when external dependence is measured by *extdepR_ Z*. In this specification it is akin to a second derivative since

$$\widehat{\beta_1} = \frac{\partial^2 markup}{\partial FIN \ \partial EXTDEP}$$

It shows by how much the marginal influence of external dependence on the markup changes in response to a marginal change in financial depth. In order to get a sense of its magnitude we next take an example using the 25th and 75th percentiles of financial depth and external dependence. According to the Rajan-Zingales measure of external finance, the industry at the 25th percentile of dependence is Beverages while the 75th percentile corresponds to Machinery. The country at the 25th percentile of financial depth, as measured by *llgdp*, is France and at the 75th percentile is Spain. If Beverages moves from France to Spain's level of financial depth then the markup changes by:

$$\mu^{new}_{Beverages} - \mu^{old}_{Beverages} = \widehat{\beta}_3(FIN_{Spain} - FIN_{France})$$
$$+\widehat{\beta_1}(FIN_{Spain} EXTDEP_{Beverages}) - \widehat{\beta_1}(FIN_{France} EXTDEP_{Beverages})$$

If Machinery moves from France to Spain's level of financial depth then the markup changes by:

$$\mu^{new}_{Machinery} - \mu^{old}_{Machinery} = \widehat{\beta}_3(FIN_{Spain} - FIN_{France})$$
$$+\widehat{\beta_1}(FIN_{Spain}EXTDEP_{Machinery}) - \widehat{\beta_1}(FIN_{France}EXTDEP_{Machinery})$$

The differential effect is calculated by

$$(\mu^{new}_{Machinery} - \mu^{old}_{Machinery}) - (\mu^{new}_{Beverages} - \mu^{old}_{Beverages}) =$$
$$\widehat{\beta_1}(FIN_{Spain} - FIN_{France})(EXTDEP_{Machinery} - EXTDEP_{Beverages}) = -0.02$$

The interpretation of this number is as follows. Given a move from France's level of financial depth to Spain's, the Machinery markup should decrease 2 percent more than the Beverages markup.

In summary, this section shows that there is evidence that financial depth has a greater effect on competition in sectors where firms are unusually dependent on external finance. However, the results are not robust to different measures of external dependence. There is some evidence that *banking freedom* has higher explanatory power compared to other measures of financial depth.

### 3.4.3 Specification III: Openness and Competition

#### Results from industry-country specific estimations

Equation (3.8) can be used to estimate the relation between competition and trade openness for each of the 50 industries in the 8 Eurozone member states and the USA for the period 1981-2004. The cross-sectional equation for each of the 450 industries has the following form:

$$y_t = \beta_0 x_t + \beta_1 OPEN_t x_t + \varepsilon_t \tag{3.19}$$

The empirical estimation gives weak evidence that a higher degree of trade openness decreases markups. The estimated coefficient $\beta_1$ is significant for 107 out of 450 regressions (10% significance level).

Although the evidence that openness leads to lower markups is weak, it is interesting to check whether the industries for which openness has significant explanatory power share a common characteristic, that of high tradedness. De Gregorio, Giovannini and Wolf (1994) define agriculture, mining, manufacturing and transportation as "tradable" whereas services other than transportation are "nontradable". Interestingly enough, we find that the industries where openness has a significant impact on their competitiveness are mostly the "tradable" ones (57%).

### Estimations at industry level

A more restrictive approach in examining the effect of trade openness on competition is to assume that the markup is industry specific. So, if markups are homogeneous across countries then (3.8) can be estimated per industry. The estimation model is:

$$y_{tk} = \beta_0 x_{tk} + \beta_1 x_{tk} OPEN_{tk} + \varepsilon_t \tag{3.20}$$

and is estimated by simple pooled OLS for 50 industries. Heteroskedasticity-robust standard errors are used. The estimated coefficient $\beta_1$ often has the correct sign but is significant for only 11 of the 50 regressions (10% significance level). However, if within-cluster correlations are assumed to be negligible, this number doubles.

Similar to section 3.1.2 on financial development, we use panel data to control for differences in intercepts. Adding time and country dummy variables as explanatory variables does not change the results much. The same is true if time and country dummy variables plus an interaction term between $x_{tk}$ and country variables are added. Table 9 shows the results of this section.

It is worth noting that the findings of this section support the hypothesis that openness has a stronger effect on the competitiveness of tradable industries. More specifically, for the three specifications of this section, 63%, 71% and 89% of the regressions for which openness is significant are for tradabale industries (clustering by country).

Tobacco (sector 16), Manufacturing (sector 36), Other inland transportation (sector 60) and Other service activities (sector 93) are the industries which are found to exhibit a sensitive relationship between competition and openness in all three specifications of this section.

### Pooled Data

If the data from different industries and countries are pooled, the results suggest that openness has a negative and significant impact on markups. The finding is robust to clustering by country, controlling for industry-specific effects as well as allowing tradable and nontradable industries to have different intercepts (see table 10).

### A "two-stage" approach

The familiar robustness check in the form of a "two-stage" approach is the next step. The estimated markup from (3.4) is the dependent variable and the control variables are trade openness and the logarithm of GDP (both time averaged) and industry dummies. Since there is no time variation, data is cross-sectional. Table 11 shows that openness has strong explanatory power for markups. Again, the result is robust to clustering by country, as well as dummies for the tradedness of the sectors.

The empirical investigation of the relation between trade openness and product market competition supports the hypothesis that greater trade openness is linked with smaller markups. The data suggest that this relation is stronger for industries characterized by a higher degree of tradedness. Furthermore, comparing the results with the findings of the previous two sections, the degree of openness of a country might be more important for lower markups than financial development. The natural next step is to control simultaneously for trade openness and financial development and their impact on competition.

### 3.4.4 Specification IV: Financial Development and Openness Together

#### Results from industry-country specific estimations

To control simultaneously for the significance of financial development and trade openness on competition, specification (3.9) is estimated for the 50 sectors of the 9 countries. Table 12 presents the results of the estimation of the 450 cross-sectional equations. Both control variables are often insignificant. However, trade openness seem to have some explanatory power for more industries than does financial development.[8]

#### Estimations at industry level

For the estimations of this section the markups of an industry are assumed to be homogeneous across the 9 countries of the sample. Treating the parameters as the same across countries we pool the data over time and estimate (3.9) per industry. The findings do not provide strong evidence for the hypothesis that the financial development or the trade openness of a country have some explanatory power on the competition of industries. However, trade openness appears again to be significant for more regressions than financial development (see Table 13).

It is interesting to note that the three of the four industries that were repeatedly found to exhibit a sensitive relationship between competition and the explanatory variables in section 3.4.3 (Tobacco, Manufacturing and Other service activities) are

[8] Similarly to section 3.4.1., the measure *bankfreed* is not used due to the small number of observations.

included in the industries that for which openness has explanatory power over competition when any of the four measures of financial development is used (the rest are Food and Beverages (15), Fabricated Metal (28) and Research & Development (73).

#### Pooled Data

If the data are pooled (industry and country parameters are assumed to be the same) the evidence becomes clearer. Although both financial development and trade openness have a negative relation with markups, financial development is not significant for all four measures of $FIN$. Contrary to that, trade openness is always significant. This finding is robust to clustering by country (see Table 14).

#### A "two-stage" approach

We do a robustness check by using the estimates of markups from (3.4) for the 450 industries as the dependent variable and time-averaged data of financial development, trade openness and GDP, the cross -sectional analysis as explanatory variables. We also add industry dummies or dummies for tradable industries. The above results are verified. Table 15 shows that trade openness has a negative and significant impact on markups whereas financial development and GDP do not have much explanatory power.

The overall findings of this section suggest that both financial development and trade openness have a negative impact on markups. However, the simultaneous inclusion of the two variables as independent variables suggests that trade openness has greater explanatory power for the extent of competition.

### 3.4.5 Further robustness checks

From the estimations of Specification I, II and IV, the measure *bankfreed* stands out as the measure of financial development with the highest significance. This finding may lead to concerns that *bankfreed* appears to have explanatory power compared to other measures simply due to the shorter time period that the data cover. Hence, the above regressions of Specifications I, II and IV were estimated for the shorter period 1995-2004 (apart from the "per industry per country" specification as there would only be 10 observations per regression in that case). It should be noted that for the estimations of the "two-stage" approach we use the markups which Christopoulou and Vermeulen (2008) have estimated for 1993-2004. These markups are estimated using a small number of observations and thus there is the possibility of measurement error in our dependent variable. This would lead to a smaller $R^2$ and higher standard errors but will not bias our estimates.

All results are given at the Appendix. Overall, we find that there is stronger evidence supporting our hypotheses. We give some indicative examples. Specification I shows that the significance of financial development, measured by *llgdp*, *prib* and *pribof*, at industry-country level is stronger or stays the same, compared to the whole period (see Table 16). Moreover, the evidence in favour of our hypotheses is stronger for these three measures of financial depth compared to *bankfreed*. Similarly, evidence appears to be stronger for the hypothesis of Specification II (see Tables 19 (i-ix). It is interesting to note that this "improvement" in significance is particularly skewed towards the explanatory power of *banking dependence*. Finally, Specification IV shows that the relation between financial depth (and trade openness) and competition is stronger for the subperiod of interest when we estimate the specification per industry.

Summarizing, we interpret these findings as a sign that financial development of the countries has been more effective for the decrease of markups in the Eurozone and US over the period 1995-2004 compared to 1981-2004. If such a result is driven by the 8 Eurozone member states it may be related to the various regulations for financial markets and the adoption of the Euro (the Euro was introduced as an accounting currency on 1 January 1999).

In the descriptive statistics section it was explained that the US drives the unusual correlation between GDP and trade openness. Moreover, the US is different compared to the Eurozone countries in many ways. This might raise concerns that pooling all countries together may generate some bias. The regression estimates are not sensitive to the inclusion of the US.

## 3.5 Conclusion

This paper suggests that financial development lead to lower markups in the Eurozone and US over the period 1981-2004. Moreover, there is evidence that financial depth has a greater effect on competition in sectors where firms are unusually dependent on external finance. This relation is stronger over the period 1995-2004, perhaps due to the increased implementation of the EU Directives about the financial services industry and the adoption of the Euro. However, these results are not robust to the use of different measures for financial development or external dependence. Furthermore, there is strong evidence that the trade openness of countries is linked with higher competition and thus lower markups. This finding appears to be stronger for industries traditionally defined as tradable. Controlling simultaneously for trade openness and financial development shows that trade openness has greater explanatory power for the extent of competition compared to financial depth.

What remains an open question is why openness has explanatory power for the extent of competition. Is it because it captures cross-country variation in the sense that more open countries have lower markups overall? Or is it due to cross-time effects i.e. more opening a country over time leads to smaller markups? Moreover, is there some natural clustering and openness has relatively higher significance for particular industries? Answering these questions would be natural extension of our work.

# 3.6 Appendix
## TABLES

### Table 1
### Specification I: per industry

| | $y=\beta_0 x+\beta_1 xFIN+\varepsilon$ | | | | | |
|---|---|---|---|---|---|---|
| | cluster by country | | | No cluster | | |
| | 10% | 5% | $\beta_1<0$ | 10% | 5% | $\beta_1<0$ |
| llgdp | 12 | 8 | 28 | 19 | 15 | 28 |
| prib | 0 | 0 | 32 | 8 | 4 | 32 |
| pribof | 3 | 1 | 29 | 9 | 5 | 29 |
| bankfreed | 7 | 6 | 26 | 14 | 8 | 26 |

Notes: The above numbers indicate the number of industries for which the interaction term is statistically significant at the 10%, 5% level or that $\beta_1$ is negative. The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. Heteroskedasticity-robust standard errors are used.

### Table 2
### Specification I: per industry

| | $y=\beta_0 x+\beta_1 xFIN+D_t+D_k+\varepsilon$ | | | | | |
|---|---|---|---|---|---|---|
| | cluster by country | | | No cluster | | |
| | 10% | 5% | $\beta_1<0$ | 10% | 5% | $\beta_1<0$ |
| llgdp | 13 | 9 | 30 | 19 | 16 | 30 |
| prib | 3 | 2 | 30 | 6 | 3 | 30 |
| pribof | 2 | 1 | 29 | 7 | 4 | 29 |
| bankfreed | 6 | 3 | 25 | 10 | 8 | 25 |

Notes: The above numbers indicate the number of industries for which the interaction term is statistically significant at the 10%, 5% level or that $\beta_1$ is negative. The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. $D_t$ and $D_k$ are time and country dummies respectively. Heteroskedasticity-robust standard errors are used.

### Table 3
### Specification I: per industry

| | $y=\beta_0 xDk+\beta_1 xFIN+D_t+D_k+\varepsilon$ | | | | | |
|---|---|---|---|---|---|---|
| | cluster by country | | | No cluster | | |
| | 10% | 5% | $\beta_1<0$ | 10% | 5% | $\beta_1<0$ |
| llgdp | 4 | 4 | 29 | 6 | 4 | 29 |
| prib | 6 | 1 | 27 | 5 | 3 | 27 |
| pribof | 9 | 5 | 26 | 5 | 10 | 26 |
| bankfreed | 14 | 6 | 20 | 13 | 6 | 20 |

Notes: The above numbers indicate the number of industries for which the interaction term is statistically significant at the 10%, 5% level or that $\beta_1$ is negative. The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. $D_t$ and $D_k$ are time and country dummies respectively. Heteroskedasticity-robust standard errors are used.

**Table 4**
**Specification I: "Two-stage" approach**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| **lngdp** | 0.025 | | 0.023 | | 0.038 | | 0.024 | |
| | (0.019) | (0.013)** | (0.020) | (0.012)* | (0.025) | (0.016)** | (0.016) | (0.012)* |
| **llgdp** | -0.189 | | | | | | | |
| | (0.238) | (0.131) | | | | | | |
| **prib** | | | -0.144 | | | | | |
| | | | (0.166) | (0.083)* | | | | |
| **pribof** | | | | | -0.136 | | | |
| | | | | | (0.125) | (0.067)** | | |
| **bankfreed** | | | | | | | 0.000 | |
| | | | | | | | (0.002) | (0.001) |
| **industry dummies** | Yes | | Yes | | Yes | | Yes | |
| **clustered at country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.94 | | 0.95 | | 0.95 | | 0.94 | |
| N | 447 | | 447 | | 447 | | 447 | |

Notes: The dependent variable is the markup estimated by Christopoulou and Vermeulen (2008) for 50 NACE industries in 9 different countries for 1981-2004. llgdp: Liquid liabilities relative to GDP. prib: Private credit by deposit money banks relative to GDP. pribof: Private credit by deposit money banks and other financial institutions relative to GDP. bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. Standard errors are clustered by country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

**Table 5**
**Specification II: Pooled Data**

## (5i) Rajan-Zingales measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bank freed | (8) |
|---|---|---|---|---|---|---|---|---|
| **x** | 0.113 | | 0.139 | | 0.124 | | 0.130 | |
| | (0.024)** | (0.024)** | (0.026)** | (0.018)** | (0.021)** | (0.013)** | (0.059)* | (0.052)** |
| **xfin** | 0.041 | | 0.001 | | 0.020 | | 0.000 | |
| | (0.041) | (0.034) | (0.031) | (0.021) | (0.023) | (0.013) | (0.001) | (0.001) |
| **xextdep** | 0.061 | | -0.001 | | 0.016 | | -0.204 | |
| | (0.058) | (0.095) | (0.079) | (0.066) | (0.042) | (0.049) | (0.152) | (0.146) |
| **xfinextdep** | -0.102 | | -0.005 | | -0.027 | | 0.003 | |
| | (0.093) | (0.119) | (0.115) | (0.071) | (0.054) | (0.042) | (0.002) | (0.002) |
| **clustered at country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.43 | | 0.42 | | 0.42 | | 0.38 | |
| N | 4267 | | 4267 | | 4311 | | 1914 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Rajan and Zingales(1998). Standard errors are clustered by country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (5ii) Maudos-Fernandez de Guevara measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| x | 0.019 | | 0.145 | | 0.158 | | -0.362 | |
| | (0.209) | (0.119) | (0.149) | (0.102) | (0.116) | (0.079)** | (0.301) | (0.194)* |
| xfin | 0.152 | | -0.037 | | -0.051 | | 0.007 | |
| | (0.302) | (0.159) | (0.161) | (0.106) | (0.091) | (0.064) | (0.005) | (0.003)** |
| xextdep | 0.449 | | 0.173 | | 0.145 | | 1.252 | |
| | (0.414) | (0.251)* | (0.277) | (0.221) | (0.230) | (0.170) | (0.664)* | (0.418)** |
| xfinextdep | -0.364 | | 0.051 | | 0.086 | | -0.015 | |
| | (0.590) | (0.339) | (0.289) | (0.228) | (0.165) | (0.136) | (0.010) | (0.006)** |
| clustered at country level | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.51 | | 0.51 | | 0.51 | | 0.46 | |
| N | 9329 | | 9329 | | 9425 | | 4145 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Maudos and Fernandez de Guevara (2007). Standard errors are clustered by country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (5iii) Carlin-Mayer measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| x | 0.124 | | 0.156 | | 0.125 | | 0.085 | |
| | (0.025)** | (0.018)** | (0.031)** | (0.020)** | (0.020)** | (0.010)** | (0.046) | (0.030)** |
| xfin | 0.024 | | -0.022 | | 0.020 | | 0.001 | |
| | (0.038) | (0.028) | (0.033) | (0.022) | (0.027) | (0.012) | (0.001) | (0.001) |
| xbankdep | 0.042 | | 0.004 | | 0.032 | | 0.027 | |
| | (0.022)* | (0.018)** | (0.034) | (0.026) | (0.017) | (0.010)** | (0.022) | (0.021) |
| xfinbankdep | -0.045 | | 0.012 | | -0.025 | | -0.000 | |
| | (0.036) | (0.030) | (0.034) | (0.028) | (0.022) | (0.015)* | (0.000) | (0.000) |
| clustered at country level | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.50 | | 0.50 | | 0.50 | | 0.46 | |
| N | 3092 | | 3092 | | 3124 | | 1392 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Carlin and Mayer (2003). Standard errors are clustered by country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## Table 6 i-ix
## Specification II: Pooled Data

### (6i) Rajan-Zingales measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| **xfin** | 0.013 | | 0.033 | | 0.016 | | -0.001 | |
| | (0.036) | (0.039) | (0.022) | (0.019)* | (0.016) | (0.016) | (0.001) | (0.001) |
| **xfinextdep** | -0.109 | | -0.014 | | -0.024 | | 0.002 | |
| | (0.102) | (0.101) | (0.095) | (0.065) | (0.052) | (0.037) | (0.002) | (0.001) |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| **$R^2$** | 0.48 | | 0.47 | | 0.47 | | 0.48 | |
| **N** | 4267 | | 4267 | | 4311 | | 1914 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Rajan and Zingales(1998). All regressions include country, industry and time dummies as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

### (6ii) Maudos-Fernandez de Guevara measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| **xfin** | 0.056 | | 0.015 | | -0.028 | | 0.003 | |
| | (0.133) | (0.112) | (0.120) | (0.082) | (0.067) | (0.048) | (0.002) | (0.002)* |
| **xfinextdep** | -0.192 | | 0.023 | | 0.081 | | -0.008 | |
| | (0.283) | (0.245) | (0.235) | (0.163) | (0.131) | (0.095) | (0.004)* | (0.003)** |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| **$R^2$** | 0.68 | | 0.68 | | 0.68 | | 0.62 | |
| **N** | 9329 | | 9329 | | 9425 | | 4145 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Maudos and Fernandez de Guevara (2007). All regressions include country, industry and time dummies as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (6iii) Carlin-Mayer measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| **xfin** | -0.037 | | -0.017 | | -0.006 | | -0.002 | |
| | (0.031) | (0.029) | (0.020) | (0.019) | (0.017) | (0.015) | (0.001)* | (0.001) |
| **xfinbankdep** | -0.041 | | 0.016 | | -0.022 | | -0.000 | |
| | (0.034) | (0.028) | (0.029) | (0.026) | (0.020) | (0.013)* | (0.000) | (0.000) |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| **$R^2$** | 0.56 | | 0.56 | | 0.56 | | 0.53 | |
| **N** | 3092 | 3092 | 3092 | | 3124 | | 1392 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Carlin and Mayer (2003). All regressions include country, industry and time dummies as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (6iv) Rajan-Zingales measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| **xfin** | -0.001 | | 0.032 | | 0.011 | | -0.001 | |
| | (0.035) | (0.038) | (0.023) | (0.020) | (0.015) | (0.015) | (0.001) | (0.001) |
| **xfinextdep** | -0.096 | | -0.020 | | -0.026 | | 0.002 | |
| | (0.101) | (0.096) | (0.091) | (0.064) | (0.054) | (0.037) | (0.002) | (0.001) |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| **$R^2$** | 0.55 | | 0.55 | | 0.55 | | 0.48 | |
| **N** | 4267 | | 4267 | | 4311 | | 1914 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Rajan and Zingales (1998). All regressions include country dummies, industry dummy*time dummy as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (6v) Maudos-Fernandez de Guevara measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| **xfin** | 0.067 | | 0.012 | | -0.024 | | 0.003 | |
| | (0.131) | (0.105) | (0.114) | (0.079) | (0.065) | (0.046) | (0.002) | (0.002)** |
| **xfinextdep** | -0.218 | | 0.026 | | 0.068 | | -0.008 | |
| | (0.278) | (0.229) | (0.225) | (0.158) | (0.129) | (0.092) | (0.005)* | (0.003)** |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.72 | | 0.72 | | 0.72 | | 0.62 | |
| N | 9329 | | 9329 | | 9425 | | 4145 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Maudos and Fernandez de Guevara (2007). All regressions include country dummies, industry dummy*time dummy as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (6vi) Carlin-Mayer measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| **xfin** | -0.038 | | -0.017 | | -0.010 | | -0.002 | |
| | (0.034) | (0.028) | (0.019) | (0.018) | (0.016) | (0.014) | (0.001)* | (0.001) |
| **xfinbankdep** | -0.036 | | 0.022 | | -0.016 | | -0.000 | |
| | (0.037) | (0.025) | (0.024) | (0.023) | (0.020) | (0.012) | (0.000) | (0.000) |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.62 | | 0.62 | | 0.62 | | 0.53 | |
| N | 3092 | | 3092 | | 3124 | | 1392 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Carlin and Mayer (2003). All regressions include country dummies, industry dummy*time dummy as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (6vii) Rajan-Zingales measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| **xfin** | 0.024 | | 0.065 | | 0.010 | | -0.000 | |
| | (0.046) | (0.048) | (0.044) | (0.034)* | (0.028) | (0.025) | (0.001) | (0.001) |
| **xfinextdep** | -0.120 | | -0.039 | | -0.024 | | 0.001 | |
| | (0.084) | (0.087) | (0.080) | (0.054) | (0.046) | (0.032) | (0.001) | (0.001) |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.52 | | 0.52 | | 0.52 | | 0.54 | |
| N | 4267 | | 4267 | | 4311 | | 1914 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Rajan and Zingales (1998). All regressions include industry dummies, country dummy*time dummy as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (6viii) Maudos-Fernandez de Guevara measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| **xfin** | 0.015 | | 0.017 | | -0.047 | | 0.002 | |
| | (0.136) | (0.117) | (0.135) | (0.095) | (0.075) | (0.055) | (0.002) | (0.002) |
| **xfinextdep** | -0.140 | | 0.074 | | 0.106 | | -0.006 | |
| | (0.267) | (0.236) | (0.221) | (0.156) | (0.124) | (0.092) | (0.003) | (0.003)** |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.69 | | 0.69 | | 0.69 | | 0.65 | |
| N | 9329 | | 9329 | | 9425 | | 4145 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Maudos and Fernandez de Guevara (2007). All regressions include industry dummies, country dummy*time dummy as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (6ix) Carlin-Mayer measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| **xfin** | -0.092 | | -0.062 | | -0.066 | | -0.003 | |
| | (0.051)* | (0.049)* | (0.030)** | (0.034)* | (0.037)* | (0.031)** | (0.001)** | (0.001)** |
| **xfinbankdep** | -0.036 | | 0.017 | | -0.020 | | -0.000 | |
| | (0.029) | (0.027) | (0.027) | (0.026) | (0.016) | (0.012)* | (0.000) | (0.000) |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| **$R^2$** | 0.62 | | 0.62 | | 0.63 | | 0.60 | |
| **N** | 3092 | | 3092 | | 3124 | | 1392 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Carlin and Mayer (2003). All regressions include industry dummies, country dummy*time dummy as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

# Table 7
# Specification II: "Two-stage" approach

## (7i) Carlin-Mayer measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| **lngdp** | 0.025 | | 0.024 | | 0.023 | | 0.026 | |
| | (0.016) | (0.018) | (0.014) | (0.016) | (0.016) | (0.015) | (0.013) | (0.017) |
| **fin** | 0.007 | | -0.181 | | 0.097 | | 0.003 | |
| | (0.095) | (0.107) | (0.156) | (0.149) | (0.101) | (0.105) | (0.002) | (0.002) |
| **finextdep** | -0.007 | | 0.206 | | -0.169 | | -0.003 | |
| | (0.129) | (0.119) | (0.221) | (0.205) | (0.159) | (0.150) | (0.003) | (0.003) |
| **Industry dummies** | Yes | | Yes | | Yes | | Yes | |
| **clustered at country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| **$R^2$** | 0.98 | | 0.98 | | 0.99 | | 0.98 | |
| **N** | 144 | | 144 | | 144 | | 144 | |

Notes: The dependent variable is the markup estimated by Christopoulou and Vermeulen (2008) for 50 NACE industries in 9 different countries for 1981-2004. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Carlin and Mayer (2003). Standard errors are clustered by industry-country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (7ii) Rajan-Zingales measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| **lngdp** | 0.021 | | 0.019 | | 0.021 | | 0.021 | |
| | (0.013) | (0.014) | (0.011) | (0.013) | (0.013) | (0.012) | (0.011) | (0.014) |
| **fin** | 0.133 | | 0.012 | | 0.051 | | 0.002 | |
| | (0.117) | (0.088) | (0.099) | (0.069) | (0.048) | (0.035) | (0.001) | (0.001)* |
| **finextdep** | -0.476 | | -0.306 | | -0.161 | | -0.002 | |
| | (0.100)** | (0.185)* | (0.092)* | (0.123)* | (0.059)* | (0.070)* | (0.002) | (0.002) |
| **industry dummies** | Yes | | Yes | | Yes | | Yes | |
| **clustered at country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| **$R^2$** | 0.99 | | 0.99 | | 0.99 | | 0.99 | |
| **N** | 198 | | 198 | | 198 | | 198 | |

Notes: The dependent variable is the markup estimated by Christopoulou and Vermeulen (2008) for 50 NACE industries in 9 different countries for 1981-2004. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Rajan and Zingales (1998). Standard errors are clustered by country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (7iii) Maudos-Fernandez de Guevara measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| **lngdp** | 0.029 | | 0.027 | | 0.042 | | 0.029 | |
| | (0.019) | (0.013)* | (0.020) | (0.012)* | (0.025) | (0.016)** | (0.017) | (0.013)* |
| **fin** | -0.258 | | -0.266 | | -0.363 | | -0.001 | |
| | (0.446) | (0.375) | (0.330) | (0.280) | (0.206) | (0.171)* | (0.004) | (0.004) |
| **finextdep** | 0.196 | | 0.326 | | 0.522 | | 0.001 | |
| | (0.767) | (0.868) | (0.622) | (0.649) | (0.310) | (0.377) | (0.008) | (0.008) |
| **industry dummies** | Yes | | Yes | | Yes | | Yes | |
| **clustered at country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| **$R^2$** | 0.95 | | 0.95 | | 0.95 | | 0.95 | |
| **N** | 429 | | 429 | | 429 | | 429 | |

Notes: The dependent variable is the markup estimated by Christopoulou and Vermeulen (2008) for 50 NACE industries in 9 different countries for 1981-2004. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Maudos and Fernandez de Guevara (2007). Standard errors are clustered by country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## Table 8

| NACE Description | NACE, Rev 1.1 | *extdepR_Z* | $\frac{\partial \mu}{\partial \text{llgdp}}$ | $\frac{\partial \mu}{\partial \text{prib}}$ | $\frac{\partial \mu}{\partial \text{pribof}}$ | $\frac{\partial \mu}{\partial \textit{bankfreed}}$ |
|---|---|---|---|---|---|---|
| Tobacco | 16 | -0.45 | 0.3472 | 0.1497 | 0.1235 | 0.0029 |
| Leather, leather and footwear | 19 | -0.11 | 0.1854 | 0.0457 | 0.0687 | 0.0022 |
| Wearing apparel, dressing and dying of fur | 18 | 0.03 | 0.1187 | 0.0028 | 0.0462 | 0.0019 |
| Basic metals | 27 | 0.05 | 0.1092 | -0.0033 | 0.0430 | 0.0019 |
| Food and beverages | 15 | 0.1 | 0.0854 | -0.0186 | 0.0349 | 0.0018 |
| Other non-metallic mineral | 26 | 0.15 | 0.0616 | -0.0339 | 0.0269 | 0.0017 |
| Textiles | 17 | 0.16 | 0.0568 | -0.0370 | 0.0252 | 0.0017 |
| Pulp, paper and paper | 21 | 0.17 | 0.0521 | -0.0400 | 0.0236 | 0.0017 |
| Coke, refined petroleum and nuclear fuel | 23 | 0.19 | 0.0426 | -0.0461 | 0.0204 | 0.0016 |
| Printing, publishing and reproduction | 22 | 0.2 | 0.0378 | -0.0492 | 0.0188 | 0.0016 |
| Fabricated metal | 28 | 0.24 | 0.0188 | -0.0614 | 0.0124 | 0.0015 |
| Wood and of wood and cork | 20 | 0.28 | -0.0003 | -0.0737 | 0.0059 | 0.0014 |
| Manufacturing nec | 36 | 0.36 | -0.0384 | -0.0982 | -0.0070 | 0.0013 |
| Motor vehicles, trailers and semi-trailers | 34 | 0.39 | -0.0526 | -0.1073 | -0.0118 | 0.0012 |
| Other transport equipment | 35 | 0.39 | -0.0526 | -0.1073 | -0.0118 | 0.0012 |
| Machinery, nec | 29 | 0.45 | -0.0812 | -0.1257 | -0.0215 | 0.0011 |
| Rubber and plastics | 25 | 0.69 | -0.1954 | -0.1991 | -0.0601 | 0.0006 |
| Electrical machinery and apparatus, nec | 31 | 0.77 | -0.2335 | -0.2236 | -0.0730 | 0.0005 |
| Chemicals and chemical products | 24 | 0.86 | -0.2764 | -0.2512 | -0.0875 | 0.0003 |
| Medical, precision and optical instruments | 33 | 0.96 | -0.3240 | -0.2818 | -0.1036 | 0.0001 |
| Radio, television and communication equipment | 32 | 1.04 | -0.3620 | -0.3062 | -0.1164 | -0.0001 |
| Office, accounting and computing machinery | 30 | 1.06 | -0.3716 | -0.3124 | -0.1197 | -0.0001 |

Notes: Calculations use $\hat{\beta}1$ and $\hat{\beta}2$ from equation (16). llgdp: Liquid liabilities relative to GDP. prib: Private credit by deposit money banks relative to GDP. pribof: Private credit by deposit money banks and other financial institutions relative to GDP. bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms.

## Table 9
## Specification III: per industry

| | cluster by country | | | No clustering | | |
|---|---|---|---|---|---|---|
| | 10% | 5% | $\beta_1<0$ | 10% | 5% | $\beta_1<0$ |
| $y= \beta\square x+ \beta_1 xOPEN+\square$ | 11 | 9 | 36 | 22 | 19 | 36 |
| $y= \beta\square x+ \beta_1 xOPEN+ \beta_2 Dt+ \beta_3 Dk +\square$ | 14 | 10 | 38 | 22 | 26 | 38 |
| $y= \beta_1 xOPEN+ \beta_2 Dt+ \beta_3 Dk + \beta 4xDk +\square$ | 9 | 7 | 26 | 13 | 9 | 26 |

Notes: The above numbers indicate the number of industries for which the interaction term xOPEN is statistically significant at the 10%, 5% level or that $\beta_1$ is negative. The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. Dt and Dk are time and country dummies respectively.

## Table 10
## Specification III: Pooled Data

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| **x** | 0.249 | | 0.254 | |
| | (0.029)** | (0.011)** | (0.027)** | (0.011)** |
| **xopen** | -0.059 | | -0.063 | |
| | (0.026)* | (0.012)** | (0.024)** | (0.012)** |
| **tradedness dummy** | No | | Yes | |
| **clustered at country level** | Yes | No | Yes | No |
| $R^2$ | 0.50 | | 0.50 | |
| N | 10213 | | 10213 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. Trade openness is the ratio of nominal exports plus imports to nominal GDP. Following De Gregorio, Giovannini and Wolf (1994), the sectors agriculture, mining, manufacturing and transportation are "tradable" whereas all other services are "nontradable". Standard errors are clustered by country in columns 1 and 3. Columns 2 and 4 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## Table 11
## Specification III: "Two stage" approach

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| **open** | -0.137 | | -0.137 | |
| | (0.060)* | (0.044)** | (0.057)** | (0.065)** |
| **lngdp** | 0.000 | | -0.000 | |
| | (0.016) | (0.015) | (0.015) | (0.019) |
| **tradedness dummy** | No | | Yes | |
| **industry dummies** | Yes | | No | |
| **clustered at country level** | Yes | No | Yes | No |
| $R^2$ | 0.95 | | 0.87 | |
| N | 447 | | 447 | |

Notes: The dependent variable is the markup estimated by Christopoulou and Vermeulen (2008) for 50 NACE industries in 9 different countries for 1981-2004. Trade openness is the ratio of nominal exports plus imports to nominal GDP. Following De Gregorio, Giovannini and Wolf (1994), the sectors agriculture, mining, manufacturing and transportation are "tradable" whereas all other services are "nontradable". Standard errors are clustered by country in columns 1 and 3. Columns 2 and 4 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## Table 12
## Specification IV: per industry per country

| $y_t = \beta\square x_t + \beta_1 x_t FIN_t + \beta_2 x_t OPEN_t + \square_t$ | | |
|---|---|---|
| | $\beta_1$ | $\beta_2$ |
| **llgdp** | 77 | 87 |
| **prib** | 76 | 82 |
| **pribof** | 78 | 83 |

Notes: The above numbers indicate the number of industries for which the interaction terms are statistically significant at the 10% level. The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP.

## Table 13
## Specification IV: per industry

| $y_t = \beta \square x + \beta_1 x FIN_{kt} + \beta_2 x_{tk} OPEN_{tk} + \square$ | | | | |
|---|---|---|---|---|
| | cluster by country | | No cluster | |
| | $\beta_1$ | $\beta_2$ | $\beta_1$ | $\beta_2$ |
| llgdp | 12 | 12 | 19 | 23 |
| prib | 3 | 11 | 11 | 22 |
| pribof | 1 | 11 | 6 | 21 |
| bankfreed | 13 | 16 | 16 | 30 |

Notes: The above numbers indicate the number of industries for which the interaction terms are statistically significant at the 10% level. The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms.

## Table 14
## Specification IV: Pooled Data

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| x | 0.261 | | 0.263 | | 0.263 | | 0.183 | |
| | (0.028)** | (0.023)** | (0.035)** | (0.019)** | (0.033)** | (0.016)** | (0.064)** | (0.055)** |
| xopen | -0.062 | | -0.061 | | -0.061 | | -0.107 | |
| | (0.025)** | (0.015)** | (0.026)** | (0.013)** | (0.025)** | (0.013)** | (0.033)** | (0.024)** |
| xfin | -0.014 | | -0.016 | | -0.014 | | 0.002 | |
| | (0.021) | (0.035) | (0.030) | (0.021) | (0.015) | (0.013) | (0.001) | (0.001)* |
| clustered at country level | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.50 | | 0.50 | | 0.50 | | 0.43 | |
| N | 9729 | | 9729 | | 9829 | | 4319 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. Trade openness is the ratio of nominal exports plus imports to nominal GDP. Following De Gregorio, Giovannini and Wolf (1994), the sectors agriculture, mining, manufacturing and transportation are "tradable" whereas all other services are "nontradable". Standard errors are clustered by country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## Table 15
## Specification IV: "Two-stage" approach

### (i)

| | (1) 1llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| **fin** | -0.069 | | -0.132 | | -0.109 | | 0.002 | |
| | (0.227) | (0.126) | (0.130) | (0.080)* | (0.121) | (0.067) | (0.002) | (0.001)** |
| **open** | -0.124 | | -0.131 | | -0.108 | | -0.185 | |
| | (0.052)** | (0.037)** | (0.067)* | (0.043)** | (0.063) | (0.041)** | (0.076)** | (0.050)** |
| **lngdp** | 0.003 | | -0.001 | | 0.016 | | -0.012 | |
| | (0.022) | (0.016) | (0.022) | (0.016) | (0.027) | (0.019) | (0.016) | (0.015) |
| **industry dummies** | Yes | | Yes | | Yes | | Yes | |
| **clustered at country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| **$R^2$** | 0.95 | | 0.95 | | 0.95 | | 0.95 | |
| **N** | 447 | | 447 | | 447 | | 447 | |

### (ii)

| | (1) 1llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| **fin** | -0.069 | | -0.131 | | -0.109 | | 0.002 | |
| | (0.215) | (0.187) | (0.125) | (0.121) | (0.114) | (0.097) | (0.002) | (0.002) |
| **open** | -0.124 | | -0.131 | | -0.108 | | -0.185 | |
| | (0.049)** | (0.071)* | (0.063)* | (0.064)** | (0.060) | (0.065)* | (0.073)** | (0.081)** |
| **lngdp** | 0.002 | | -0.001 | | 0.016 | | -0.012 | |
| | (0.021) | (0.022) | (0.021) | (0.019) | (0.026) | (0.025) | (0.015) | (0.020) |
| **tradedness dummies** | Yes | | Yes | | Yes | | Yes | |
| **clustered at country level** | Yes | No | Yes | No | Yes | No | Yes | No |
| **$R^2$** | 0.87 | | 0.87 | | 0.87 | | 0.87 | |
| **N** | 447 | | 447 | | 447 | | 447 | |

Notes for tables 15(i) and 15(ii): The dependent variable is the markup estimated by Christopoulou and Vermeulen (2008) for 50 NACE industry in 9 different countries for 1981-2004. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. Trade openness is the ratio of nominal exports plus imports to nominal GDP. Following De Gregorio, Giovannini and Wolf (1994), the sectors agriculture, mining, manufacturing and transportation are "tradable" whereas all other services are "nontradable". Standard errors are clustered by country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## Table 16
## Specification I: "per industry"
## Sample Period 1995-2004

| | $y = \beta\Box x + \beta_1 xFIN + \Box$ | | | | | |
|---|---|---|---|---|---|---|
| | cluster by country | | | No cluster | | |
| | 10% | 5% | $\beta_1<0$ | 10% | 5% | $\beta_1<0$ |
| llgdp | 18 | 12 | 36 | 17 | 14 | 36 |
| prib | 19 | 13 | 35 | 18 | 15 | 35 |
| pribof | 16 | 13 | 28 | 15 | 11 | 28 |

| | $y = \beta\Box x + \beta_1 xFIN + \beta_2 Dt + \beta_3 Dk + \Box$ | | | | | |
|---|---|---|---|---|---|---|
| | cluster by country | | | No cluster | | |
| | 10% | 5% | $\beta_1<0$ | 10% | 5% | $\beta_1<0$ |
| llgdp | 15 | 10 | 35 | 16 | 12 | 35 |
| prib | 16 | 11 | 33 | 17 | 13 | 33 |
| pribof | 18 | 11 | 28 | 18 | 10 | 28 |

| | $y = \beta_1 xFIN + \beta_2 Dt + \beta_3 Dk + \beta 4xDk + \Box$ | | | | | |
|---|---|---|---|---|---|---|
| | cluster by country | | | No cluster | | |
| | 10% | 5% | $\beta_1<0$ | 10% | 5% | $\beta_1<0$ |
| llgdp | 18 | 11 | 29 | 12 | 9 | 29 |
| prib | 16 | 10 | 30 | 12 | 6 | 30 |
| pribof | 23 | 16 | 29 | 17 | 10 | 29 |

Notes: The above numbers indicate the number of industries for which the interaction term is statistically significant at the 10%, 5% level or that $\beta_1$ is negative. The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. Dt and Dk are time and country dummies respectively.

## Table 17: Specification I: "Two stage" approach
## Sample Period 1995-2004

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| lngdp | 0.006 | | 0.009 | | 0.024 | | 0.013 | |
| | (0.021) | (0.012) | (0.022) | (0.012) | (0.025) | (0.014)* | (0.020) | (0.012) |
| llgdp | -0.208 | | | | | | | |
| | (0.125) | (0.077)** | | | | | | |
| prib | | | -0.085 | | | | | |
| | | | (0.063) | (0.040)** | | | | |
| pribof | | | | | -0.088 | | | |
| | | | | | (0.066) | (0.037)** | | |
| bankfreed | | | | | | | -0.000 | |
| | | | | | | | (0.002) | (0.001) |
| Industry dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| clustered at country level | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| N | 447 | 447 | 447 | 447 | 447 | 447 | 447 | k4 |

Notes: The dependent variable is the markup estimated by Christopoulou and Vermeulen (2008) for 50 NACE industry in 9 different countries for 1993-2004. llgdp: Liquid liabilities relative to GDP. prib: Private credit by deposit money banks relative to GDP. pribof: Private credit by deposit money banks and other financial institutions relative to GDP. bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. Standard errors are clustered by country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## Table 18 (i-iii)
## Specification II: Pooled Data, Period 1995-2004

### (18i) Rajan-Zingales measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) |
|---|---|---|---|---|---|---|
| x | 0.117 | | 0.128 | | 0.116 | |
| | (0.029)** | (0.038)** | (0.023)** | (0.028)** | (0.019)** | (0.023)** |
| xfin | 0.022 | | 0.005 | | 0.017 | |
| | (0.045) | (0.044) | (0.023) | (0.025) | (0.017) | (0.015) |
| xextdep | -0.029 | | -0.042 | | -0.030 | |
| | (0.046) | (0.106) | (0.043) | (0.088) | (0.030) | (0.068) |
| xfinextdep | -0.016 | | 0.002 | | -0.011 | |
| | (0.075) | (0.117) | (0.059) | (0.078) | (0.026) | (0.044) |
| clustered at country level | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.33 | | 0.33 | | 0.33 | |
| N | 1804 | | 1804 | | 1848 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. EXDEP: The measure of external dependence used is the one from Rajan and Zingales (1998). Standard errors are clustered by country in columns 1, 3 and 5. Columns 2, 4 and 6 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

### (18ii) Maudos-Fernandez de Guevara measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) |
|---|---|---|---|---|---|---|
| x | -0.073 | | -0.017 | | 0.019 | |
| | (0.203) | (0.151) | (0.179) | (0.131) | (0.142) | (0.103) |
| xfin | 0.153 | | 0.064 | | 0.017 | |
| | (0.252) | (0.164) | (0.168) | (0.110) | (0.095) | (0.064) |
| xextdep | 0.635 | | 0.491 | | 0.396 | |
| | (0.391) | (0.325)* | (0.353) | (0.278)* | (0.284) | (0.219)* |
| xfinextdep | -0.409 | | -0.178 | | -0.053 | |
| | (0.509) | (0.355) | (0.335) | (0.231) | (0.184) | (0.133) |
| clustered at country level | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.43 | | 0.42 | | 0.42 | |
| N | 3905 | | 3905 | | 4001 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. EXDEP: The measure of external dependence used is the one from Maudos and Fernandez de Guevara (2007). Standard errors are clustered by country in columns 1, 3 and 5. Columns 2, 4 and 6 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (18iii) Carlin-Mayer measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) |
|---|---|---|---|---|---|---|
| x | 0.133 | | 0.141 | | 0.126 | |
| | (0.032)** | (0.025)** | (0.028)** | (0.019)** | (0.023)** | (0.016)** |
| xfin | 0.001 | | -0.009 | | 0.009 | |
| | (0.037) | (0.029) | (0.021) | (0.018) | (0.020) | (0.012) |
| xextdep | 0.007 | | 0.005 | | 0.006 | |
| | (0.014) | (0.018) | (0.013) | (0.014) | (0.009) | (0.011) |
| xfinextdep | -0.004 | | -0.001 | | -0.003 | |
| | (0.021) | (0.025) | (0.016) | (0.016) | (0.010) | (0.011) |
| clustered at country level | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.43 | | 0.43 | | 0.43 | |
| N | 1312 | | 1312 | | 1344 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. EXDEP: The measure of external dependence used is the one from Carlin and Mayer (2003). Standard errors are clustered by country in columns 1, 3 and 5. Columns 2, 4 and 6 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

# Table 19 (i-ix)
# Specification II: Pooled Data
# Period 1995-2004

## (19i) Rajan-Zingales measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) |
|---|---|---|---|---|---|---|
| xfin | -0.013 | | -0.058 | | -0.010 | |
| | (0.038) | (0.044) | (0.031)* | (0.038) | (0.015) | (0.018) |
| xfinextdep | -0.082 | | -0.049 | | -0.036 | |
| | (0.076) | (0.062) | (0.059) | (0.045) | (0.032) | (0.025) |
| clustered at industry-country level | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.45 | | 0.45 | | 0.44 | |
| N | 1804 | | 1804 | | 1848 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. EXDEP: The measure of external dependence used is the one from Rajan and Zingales (1998). All regressions include country, industry and time dummies as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3 and 5. Columns 2, 4 and 6 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (19ii) Maudos-Fernandez de Guevara measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) |
|---|---|---|---|---|---|---|
| **xfin** | 0.009 | | -0.039 | | -0.033 | |
| | (0.099) | (0.084) | (0.072) | (0.061) | (0.040) | (0.034) |
| **xfinextdep** | -0.134 | | -0.039 | | 0.028 | |
| | (0.226) | (0.184) | (0.159) | (0.127) | (0.090) | (0.076) |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.61 | | 0.61 | | 0.61 | |
| N | 3905 | | 3905 | | 4001 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. EXDEP: The measure of external dependence used is the one from Maudos and Fernandez de Guevara (2007). All regressions include country, industry and time dummies as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3 and 5. Columns 2, 4 and 6 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (19iii) Carlin-Mayer measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) |
|---|---|---|---|---|---|---|
| **xfin** | -0.077 | | -0.109 | | -0.034 | |
| | (0.032)** | (0.047)* | (0.034)** | (0.044)** | (0.013)** | (0.019)* |
| **xfinbankdep** | 0.004 | | 0.005 | | 0.000 | |
| | (0.019) | (0.022) | (0.012) | (0.015) | (0.009) | (0.010) |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.54 | | 0.54 | | 0.54 | |
| N | 1312 | | 1312 | | 1344 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. EXDEP: The measure of external dependence used is the one from Carlin and Mayer (2003). All regressions include country, industry and time dummies as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3 and 5. Columns 2, 4 and 6 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (19iv) Rajan-Zingales measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) |
|---|---|---|---|---|---|---|
| **xfin** | -0.022 | | -0.051 | | -0.010 | |
| | (0.037) | (0.041) | (0.030)* | (0.036) | (0.014) | (0.016) |
| **xfinextdep** | -0.068 | | -0.041 | | -0.041 | |
| | (0.073) | (0.058) | (0.058) | (0.043) | (0.032) | (0.024)* |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.53 | | 0.53 | | 0.53 | |
| N | 1804 | | 1804 | | 1848 | |

Notes: The dependent variable is the nominal Solow residual and x is the the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. EXDEP: The measure of external dependence used is the one from Rajan and Zingales(1998). All regressions include country dummies, industry dummy*time dummy as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3 and 5. Columns 2, 4 and 6 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (19v) Maudos-Fernandez de Guevara measure

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | llgdp | | prib | | pribof | |
| **xfin** | 0.038 | | -0.008 | | -0.022 | |
| | (0.094) | (0.077) | (0.069) | (0.056) | (0.038) | (0.031) |
| **xfinextdep** | -0.187 | | -0.085 | | 0.005 | |
| | (0.214) | (0.169) | (0.153) | (0.116) | (0.085) | (0.068) |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.67 | | 0.67 | | 0.67 | |
| N | 3905 | | 3905 | | 4001 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. EXDEP: The measure of external dependence used is the one from Maudos and Fernandez de Guevara (2007). All regressions include country dummies, industry dummy*time dummy as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3 and 5. Columns 2, 4 and 6 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (19vi) Carlin-Mayer measure

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | llgdp | | prib | | pribof | |
| **xfin** | -0.074 | | -0.092 | | -0.031 | |
| | (0.032)** | (0.042)* | (0.029)** | (0.039)** | (0.012)** | (0.016)* |
| **xfinbankdep** | 0.002 | | 0.004 | | 0.002 | |
| | (0.021) | (0.019) | (0.012) | (0.012) | (0.010) | (0.008) |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.61 | | 0.61 | | 0.61 | |
| N | 1312 | | 1312 | | 1344 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. EXDEP: The measure of external dependence used is the one from Carlin and Mayer (2003). All regressions include country dummies, industry dummy*time dummy as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3 and 5. Columns 2, 4 and 6 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (19vii) Rajan-Zingales measure

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | llgdp | | prib | | pribof | |
| **xfin** | 0.005 | | -0.067 | | -0.006 | |
| | (0.061) | (0.070) | (0.057) | (0.068) | (0.029) | (0.031) |
| **xfinextdep** | -0.109 | | -0.080 | - | -0.042 | |
| | (0.069) | (0.053)** | (0.052) | (0.038)** | (0.030) | (0.022)* |
| **clustered at industry-country level** | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.50 | | 0.50 | | 0.49 | |
| N | 1804 | | 1804 | | 1848 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. EXDEP: The measure of external dependence used is the one from Rajan and Zingales(1998). All regressions include industry dummies, country dummy*time dummy as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3 and 5. Columns 2, 4 and 6 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (19viii) Maudos-Fernandez de Guevara measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) |
|---|---|---|---|---|---|---|
| xfin | -0.095 | | -0.138 | | -0.080 | |
| | (0.106) | (0.096) | (0.086) | (0.082)* | (0.050) | (0.041)* |
| xfinextdep | -0.046 | | 0.019 | | 0.062 | |
| | (0.215) | (0.169) | (0.150) | (0.116) | (0.084) | (0.070) |
| clustered at industry-country level | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.63 | | 0.63 | | 0.63 | |
| N | 3905 | | 3905 | | 4001 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. EXDEP: The measure of external dependence used is the one from Maudos and Fernandez de Guevara (2007). All regressions include industry dummies, country dummy*time dummy as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3 and 5. Columns 2, 4 and 6 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (19ix) Carlin-Mayer measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) |
|---|---|---|---|---|---|---|
| xfin | -0.188 | | -0.315 | | -0.098 | |
| | (0.099)* | (0.089)** | (0.093)** | (0.087)** | (0.037)** | (0.033)** |
| xfinbankdep | 0.006 | | 0.006 | | 0.001 | |
| | (0.016) | (0.023) | (0.011) | (0.015) | (0.008) | (0.010) |
| clustered at industry-country level | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.60 | | 0.60 | | 0.60 | |
| N | 1312 | | 1312 | | 1344 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. EXDEP: The measure of external dependence used is the one from Carlin and Mayer (2003). All regressions include industry dummies, country dummy*time dummy as well as x*industry dummies and x*country dummies. Standard errors are clustered by industry-country in columns 1, 3 and 5. Columns 2, 4 and 6 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

Table 20
Specification II: "Two stage" approach
Period 1995-2004

## (20i) Carlin-Mayer measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| lngdp | 0.009 | | 0.009 | | 0.008 | | 0.010 | |
| | (0.018) | (0.009) | (0.019) | (0.009) | (0.019) | (0.009) | (0.015) | (0.009) |
| fin | -0.021 | | -0.016 | | 0.024 | | 0.002 | |
| | (0.047) | (0.045) | (0.033) | (0.030) | (0.038) | (0.026) | (0.002) | (0.024) |
| finextdep | -0.011 | | -0.002 | | -0.013 | | -0.000 | |
| | (0.028) | (0.036) | (0.023) | (0.026) | (0.016) | (0.023) | (0.001) | (0.001) |
| industry dummies | Yes | | Yes | | Yes | | Yes | |
| clustered at country level | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.99 | | 0.99 | | 0.99 | | 0.99 | |
| N | 144 | | 144 | | 144 | | 144 | |

Notes: The dependent variable is the markup estimated by Christopoulou and Vermeulen (2008) for 50 NACE industries in 9 different countries for 1993-2004. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is the one from Carlin and Mayer (2003). Standard errors are clustered by country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (20ii) Rajan-Zingales measure

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| lngdp | 0.007 | | 0.006 | | 0.007 | | 0.009 | |
| | (0.020) | (0.008) | (0.020) | (0.008) | (0.021) | (0.008) | (0.017) | (0.007) |
| fin | 0.006 | | 0.018 | | 0.031 | | 0.002 | |
| | (0.061) | (0.066) | (0.046) | (0.038) | (0.035) | (0.031) | (0.002) | (0.002) |
| finextdep | -0.143 | | -0.148 | | -0.070 | | 0.000 | |
| | (0.095) | (0.131) | (0.043)** | (0.073)* | (0.051) | (0.060) | (0.004) | (0.003) |
| industry dummies | Yes | | Yes | | Yes | | Yes | |
| clustered at country level | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.99 | | 0.99 | | 0.99 | | 0.99 | |
| N | 198 | | 198 | | 198 | | 198 | |

Notes: The dependent variable is the markup estimated by Christopoulou and Vermeulen (2008) for 50 NACE industries in 9 different countries for 1993-2004. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is from Rajan and Zingales(1998). Standard errors are clustered by country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## (20iii) Maudos-Fernandez de Guevara measure

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | llgdp | | prib | | pribof | | bankfreed | |
| lngdp | 0.013 | | 0.015 | | 0.029 | | 0.019 | |
| | (0.021) | (0.011) | (0.022) | (0.012) | (0.024) | (0.013)* | (0.020) | (0.011) |
| fin | -0.134 | | -0.076 | | -0.178 | | 0.001 | |
| | (0.318) | (0.222) | (0.174) | (0.139) | (0.134) | (0.102) | (0.005) | (0.004) |
| finextdep | -0.135 | | 0.003 | | 0.213 | | -0.002 | |
| | (0.519) | (0.515) | (0.317) | (0.323) | (0.236) | (0.232) | (0.009) | (0.010) |
| industry dummies | Yes | | Yes | | Yes | | Yes | |
| clustered at country level | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.95 | | 0.95 | | 0.95 | | 0.95 | |
| N | 429 | | 429 | | 429 | | 429 | |

Notes: The dependent variable is the markup estimated by Christopoulou and Vermeulen (2008) for 50 NACE industries in 9 different countries for 1981-2004. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. EXDEP: The measure of external dependence used is from Maudos and Fernandez de Guevara (2007). Standard errors are clustered by country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## Table 21
## Specification IV: Per Industry
## Period 1995-2004

| $y = \beta\square x + \beta_1 x FIN_{kt} + \beta_2 x_{ct} OPEN_{ck} + \square$ | | | | |
|---|---|---|---|---|
| | cluster by country | | No cluster | |
| | $\beta_1$ | $\beta_2$ | $\beta_1$ | $\beta_2$ |
| llgdp | 15 | 14 | 14 | 19 |
| prib | 17 | 16 | 16 | 18 |
| pribof | 17 | 17 | 16 | 22 |

Notes: The above numbers indicate the number of industries for which the interaction term is statistically significant at the 10% level. The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. Heteroskedasticity-robust standard errors are used.

**Table 22**
**Specification IV: Pooled Data**
**Period 1995-2004**

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) |
|---|---|---|---|---|---|---|
| **x** | 0.276 | | 0.276 | | 0.280 | |
| | (0.030)** | (0.038)** | (0.028)** | (0.032)** | (0.031)** | (0.028)** |
| **xopen** | -0.096 | | -0.097 | | -0.093 | |
| | (0.032)** | (0.029)** | (0.032)** | (0.024)** | (0.029)** | (0.018)** |
| **xfin** | -0.001 | | -0.000 | | -0.007 | |
| | (0.028) | (0.059) | (0.016) | (0.037) | (0.006) | (0.018) |
| **clustered at country level** | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.41 | | 0.41 | | 0.41 | |
| N | 4069 | | 4069 | | 4169 | |

Notes: The dependent variable is the nominal Solow residual and x is the difference between nominal output growth and nominal capital cost growth. FIN denotes one of the following measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP. Trade openness is the ratio of nominal exports plus imports to nominal GDP. Following De Gregorio, Giovannini and Wolf (1994), the sectors agriculture, mining, manufacturing and transportation are "tradable" whereas all other services are "nontradable". Standard errors are clustered by country in columns 1, 3 and 5. Columns 2, 4 and 6 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## Table 23 (i-ii)

### Table 23i
### Specification IV: "Two stage" approach
### Period 1995-2004

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| fin | -0.054 | | -0.012 | | -0.034 | | 0.003 | |
| | (0.179) | (0.100) | (0.049) | (0.038) | (0.070) | (0.039) | (0.002) | (0.001)** |
| open | -0.165 | | -0.187 | | -0.169 | | -0.250 | |
| | (0.095) | (0.054)** | (0.066)** | (0.041)** | (0.073)** | (0.045)** | (0.079)** | (0.053)** |
| lngdp | -0.022 | | -0.025 | | -0.017 | | -0.036 | |
| | (0.032) | (0.018) | (0.026) | (0.016) | (0.035) | (0.020) | (0.024) | (0.017)** |
| industry dummies | Yes | | Yes | | Yes | | Yes | |
| clustered at country level | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.95 | | 0.95 | | 0.95 | | 0.95 | |
| N | 447 | | 447 | | 447 | | 447 | |

### Table 23ii
### Specification IV: "Two stage" approach
### Period 1995-2004

| | (1) llgdp | (2) | (3) prib | (4) | (5) pribof | (6) | (7) bankfreed | (8) |
|---|---|---|---|---|---|---|---|---|
| fin | -0.052 | | -0.010 | | -0.035 | | 0.003 | |
| | (0.170) | (0.145) | (0.048) | (0.063) | (0.066) | (0.060) | (0.002) | (0.002) |
| open | -0.165 | | -0.188 | | -0.168 | | -0.249 | |
| | (0.090) | (0.090)* | (0.062)** | (0.071)** | (0.070)** | (0.071)** | (0.075)** | (0.079)** |
| lngdp | -0.023 | | -0.026 | | -0.017 | | -0.037 | |
| | (0.030) | (0.024) | (0.024) | (0.021) | (0.033) | (0.026) | (0.023) | (0.021)* |
| tradedness dummyies | Yes | | Yes | | Yes | | Yes | |
| clustered at country level | Yes | No | Yes | No | Yes | No | Yes | No |
| $R^2$ | 0.88 | | 0.88 | | 0.88 | | 0.88 | |
| N | 447 | | 447 | | 447 | | 447 | |

Notes for tables 23(i) and 23(ii): The dependent variable is the markup estimated by Christopoulou and Vermeulen (2008) for 50 NACE industry in 9 different countries for 1993-2004. FIN denotes one of the following four measures of financial development: llgdp: Liquid liabilities relative to GDP, prib: Private credit by deposit money banks relative to GDP, pribof: Private credit by deposit money banks and other financial institutions relative to GDP, and bankfreed: This is a composite index which measures banking security as well as banks' independence from government control with an overall score on a scale of 0 to 100 with higher values implying fewer restrictions on banking freedoms. Trade openness is the ratio of nominal exports plus imports to nominal GDP. Following De Gregorio, Giovannini and Wolf (1994), the sectors agriculture, mining, manufacturing and transportation are "tradable" whereas all other services are "nontradable". Standard errors are clustered by country in columns 1, 3, 5 and 7. Columns 2, 4, 6 and 8 report the standard errors when within-clusters correlations are assumed to be negligible. Heteroskedasticity-robust standard errors are reported in parentheses. **=significant at 5% level, *=significant at 10% level

## Data on External Dependence

**extdepR_Z**

The data used are given in Rajan and Zingales (1998) pp. 566-567. Data are given at the 3 or 4 digit level. Some explanation must be given about how their data are matched with the rest of the data of this paper. In an earlier version of the paper they quote:

Data on value added and gross fixed capital formation for each industry in each country are obtained from the Yearbook of Industrial Statistics (vol 1) database put together by the United Nations Statistics Division. We checked the data for inconsistencies, changes in classification of sectors, and changes in units. The U.N. data is classified by International SIC code. In order to obtain the amount of external dependence used by the industry in the U.S., we matched ISIC codes with SIC codes. (...) Not all the ISIC sectors for which the Yearbook of Industrial Statistics report data on value added are mutually exclusive. For example, drugs (3522) is a subsector of other chemicals (352). In these cases, the values of the broader sectors are net of the values of the subsectors that are separately reported. We follow this convention...

The revision of ISIC that Rajan and Zingales (1998) use is not mentioned. However, it seems that Revision 2 is being used. Since in the EU KLEMS database used by Christopoulou and Vermeulen (2008), data are classified according to NACE code, Revision 1.1 there was a problem of correspondence. U.N. does not give an official and direct correspondence table between the two. We use an empirical correspondence. For the few values that Rajan and Zingales (1998) report at the 4 digit level we used unweighted averages of the subsector and the broader sector. We used unweighted averages too in the cases that two or more of ISIC codes correspond to a single NACE code. The correspondence is presented in the table below.

| ISIC,Revision 2 | NACE code, Revision 1.1 |
|---|---|
| 313, 311 | 15 |
| 314 | 16 |
| 321, 3211 | 17 |
| 322 | 18 |
| 323, 324 | 19 |
| 331 | 20 |
| 341, 3411 | 21 |
| 342 | 22 |
| 353, 354 | 23 |
| 352, 3522 | 24 |

| | |
|---|---|
| 355, 356 | 25 |
| 361, 362, 369 | 26 |
| 371, 372 | 27 |
| 381 | 28 |
| 382 | 29 |
| 3825 | 30 |
| 383 | 31 |
| 3832 | 32 |
| 385 | 34 |
| 3843 | 35 |
| 384, 3841 | 36 |
| 332, 390 | 37 |

**extdepM_G**

Maudos and Fernandez de Guevara (2007) use data from Amadeus (Bureau Van Dijk), which contains financial and economic information on more than 7 million European firms. Data were obtained according to NACE but were converted according to ISIC Rev. 3.1. and then aggregated according to ISIC Rev. 3 using U.N.'s correspondence table. We reversed the procedure and used an unweighted average in the case of imperfect matches. The correspondence is presented in the table below.

| ISIC,Rev 3 | NACE, Rev 1.1 | ISIC,Rev 3 | NACE, Rev 1.1 |
|---|---|---|---|
| 5 | 15 | 32 | 41 |
| 5 | 16 | 33 | 45 |
| 6 | 17 | 34 | 50 |
| 7 | 18 | 35 | 51 |
| 8 | 19 | 36 | 52 |
| 9 | 20 | 37 | 55 |
| 10 | 21 | 38 | 60 |
| 11 | 22 | 39 | 61 |
| 12 | 23 | 40 | 62 |
| 13 | 24 | 41 | 63 |
| 14 | 25 | 42 | 64 |
| 15 | 26 | 43 | 65 |
| 16 | 27 | 45 | 67 |
| 17 | 28 | 46 | 70 |
| 18 | 29 | 47 | 71 |
| 19 | 30 | 48 | 72 |
| 21 | 31 | 49 | 73 |
| 22, 23, 24 | 32 | 50, 51 | 74 |
| 25 | 33 | 53 | 80 |
| 27 | 34 | 54 | 85 |
| 28, 29 | 35 | 55 | 90 |
| 31 | 36 | 55 | 91 |
| 31 | 37 | 55 | 92 |
| 32 | 40 | 55 | 93 |

**Bank Dependence**

The measure is flow measure derived from the sources and uses of funds constructed from the aggregate balance sheet data compiled by the Ministry of Finance.

| **NACE Description** | **NACE, Rev 1.1** | **Carlin &Mayer** |
|---|---|---|
| Food and beverages | 15 | Food, Beverages |
| Tobacco | 16 | Tobacco |
| Textiles | 17 | Textiles |
| Wearing apparel, Dressing and Dying of fur | 18 | Clothing |
| Wood and of wood and cork | 20 | Wood products |
| Pulp, paper and paper | 21 | Paper & Products |
| Printing, publishing and reproduction | 22 | Printing & Publishing |
| Chemicals and chemical products | 24 | Industrial chemicals, Other Chemicals |
| Other non-metallic minerals | 26 | Pottery, China etc, Glass & products, Non-metallic products, nec |
| Basic metals | 27 | Iron & steel, Non-ferrous metals |
| Fabricated metal | 28 | Metal products |
| Machinery, nec | 29 | Non-Electrical machinery |
| Electrical machinery and apparatus, nec | 31 | Electrical machinery |
| Medical, precision and optical instruments | 33 | Instruments |
| Motor vehicles, trailers and semi-trailers | 35 | Motor vehicles |
| Other transport equipment | 36 | Shipbuilding & Repairing |

# Chapter 4

# Inequality and growth: Does differential fertility really matter?

## 4.1 Introduction

Growth's enhancement, usually measured through the change in GDP per capita, seems to have been an easy target for the modern world. Inequality, on the other hand, is still a distressing, almost embarrassing, fact of the so-called advanced world. According to Milanovic (2002) and Milanovic and Yitzhaki (2002), the group of the most developed countries has the lowest Gini coefficient and high inequality seems to be a characteristic of less developed countries.[1] The income of the developed countries accounts for 58 percent of world income and their population accounts for 16 percent of world's population, but the income of the "Third World" is 29 percent and the population share 76 percent.

[1] Inequality is calculated from the world distribution for individuals based entirely on household survey data from several countries, and adjusted for differences in purchasing power parity between the countries.

Numerous studies try to identify why is there this relationship and which direction the causality runs. Is it inequality that affects growth or growth affects inequality or they are jointly caused? Kuznets (1955) first suggested a link running from output to income distribution with an inverted U-shaped relation. However, later studies have consistently refuted the soundness of the Kuznets hypothesis and have generated skepticism about causal links running from economic growth to inequality.[2] The evidence about the empirical link is controversial. The significance of the estimated coefficients is not always convincing and the results are often sensitive to changes in specification and other robustness tests. Benabou (1996) surveys 23 papers on the relationship between growth and inequality. He finds that in ten of these papers there is a consistent significant negative relationship. The other thirteen papers find effectively no correlation. On the other hand, some recent studies support the existence of a positive relation between income inequality and growth.[3] Possible reasons for these contradictory results are non-linearities (Banerjee and Duflo, 2003) or a more complicated causal mechanism (Lundberg and Squire, 2003).

The empirical inconclusiveness is not surprising since there are a variety of ways in which growth and inequality could be linked. The several suggested mechanisms could be classified in four categories: capital market imperfections channels (as in Galor and Zeira, 1993 or Banerjee and Newman, 1993 or Aghion and Bolton, 1997), political economy (as in Persson and Tabellini 1994 or Alesina and Rodrik, 1994 or Chang, 1998), sociopolitical unrest and conflict (as in Alesina and Perotti, 1996) and human capital (Galor and Tsiddon, 1996). Differential fertility has been recently added to suggested mechanisms and the present paper engages in its relativity.

De La Croix and Doepke (2003, henceforth DLCD) attempt to resolve this in an insightful theoretical and empirical analysis, which builds on the human capital theory of Becker and Barro (1998). They note that there are two possible channels linking inequality and growth via human capital. First, if there are diminishing returns to human capital at the individual level, then greater human capital inequality

[2] See, among others, Benabou (1996), Birdsall and Londono (1997), Ravallion and Chen (1997).
[3] See, among others, Benhabib and Spiegel (1998), Li and Zou (1998) and Forbes (2000).

will lead to lower growth (holding average education levels constant). This can be seen by considering the effect of a mean-preserving spread on human capital - the loss to the poor (whose marginal product is high) will exceed the gain to the rich (whose marginal product is low). The second channel is differential fertility. People with lower human capital will not only choose less education for their children but also choose a higher number of children. Thus, more weight is put on families who provide little education, which reduces future human capital. In their empirical result, DLCD use a panel dataset containing 68 countries over the years 1960-1992 and find that when differential fertility is included in growth regressions, it not only is a better explanatory than inequality, but that inequality ceases to matter at all. This would have two consequences. First, regarding human capital, inequality is related to growth only through the second channel proposed above: diminishing returns are not important. Secondly, there would appear to be no residual explanatory power of inequality via mechanisms (such as political economy) listed earlier.

This paper revisits the empirical relationship between inequality and growth through differences in fertility rates among individuals that belong to different income or educational groups. Focusing on the influence of differential fertility, we shall contest De La Croix and Doepke's empirical conclusions on two counts. First, we discuss some problems with their data. We show that there are particular problems with the measure of differential fertility which they use, since it is frequently based on very small proportions of different countries' populations and is thus likely to contain significant measurement error. We find that the significance of the fertility differential in their results is not robust to different measures of differential fertility or to other corrections we think are important in the data they use. Finally, we extend the econometric techniques used to analyse the relationship, in particular looking at the reliability of the instrumental variables and panel data techniques. Second, we revise the empirical relation between human capital inequality and growth and we suggest an appropriate measure of human capital inequality, which is the relevant source of inequality according to the theoretical model of DLCD. We do a robustness check with the use of various estimation methods and more general specifications.

The rest of the paper proceeds as follows. Section 1 presents the results of DLCD, our efforts to replicate them and suggest a different measure of differential fertility. Section 2 discusses some problems with the data. Section 3 suggests an appropriate measure for human capital inequality and introduces variables related to human capital in the regressions estimated by DLCD. Finally, Section 4 concludes..

## 4.2 Problems with Replication

DLCD treat fertility and education decisions as interdependent and endogenous and build a theoretical model, which reflects the common hypothesis of a trade-off between the quality and quantity of children. Their framework suggests that an increase in human inequality increases the education inequality and the fertility differential between the rich and the poor. Since the production function for the human capital is concave and poor families who invest little in education will form a large fraction of next generation's population, the future average education of the economy will be lower, it will accumulate less human capital and therefore grow slower. The dynamic behavior of their economy is characterized by a degenerate long-run distribution; hence there is no inequality among households along the balanced growth path.

DLCD mention that the first part of their hypothesis, the link from income inequality to high fertility differentials, has been analyzed by Kremer and Chen (2002) who find that the Gini coefficient has a positive relation with fertility differentials. To test the second part of their argument, the link from the differential fertility to growth, DLCD introduce a differential-fertility variable into a standard growth regression.[4] The regression equation is estimated for a panel data set for 83 developed

[4]The theoretical analysis of DLCD predicts that inequality is transitory in the model and disappears in the balanced growth path. Hence, a change in inequality and therefore in differential fertility affects the steady-state level of output but not the long term growth rate. However, the empirical analysis focuses on the relation between differential fertility and the growth rate of GDP per capita instead of the level of GDP per capita. This allows for a dynamic relationship between GDP and differential fertility. In any case, if the adjustment to the new steady-state position takes

and developing countries over the periods 1960-1976 and 1976-1992. (The years and the number of countries are mainly constrained by the availability of differential fertility data). The dependant variable (GR) is the average annual growth rate of GDP per capita, continuously compounded and expressed as percentages. Differential fertility (DTFR) is defined as the difference in the total fertility rate between women with the highest and the lowest education level. The remaining independent variables are log of initial GDP per capita (GDP), the average ratio of investment to GDP (I/GDP), the average ratio of government expenditure to GDP (G/GDP), a dummy variable for African countries (AFR), the Gini coefficient for the initial income distribution (GINI) and initial total fertility (TFR). They allow the constant to differ across periods; Constant A for the first period and Constant B for the second period. They employ the Generalized Method of Moments (GMM) to estimate the regression equation and instrument I/GDP, G/GDP, GINI and DTFR to correct for possible endogeneity. The instruments used are: constant, log of initial GDP per capita, log of initial GDP per capita squared, initial I/GDP ratio, initial G/GDP ratio, initial fertility, initial fertility squared, initial life expectancy, initial life expectancy squared, Africa dummy, and the tropics and access to the sea variables of Sachs and Warner (1997).[5]

Table 1 gives the descriptive statistics which DLCD provide in their paper whereas Table 2 gives their estimation results. The investment rate has a positive and significant effect on growth whereas initial GDP, the government expenditure rate and the African dummy have a negative and significant effect (Regression 1). In Regression (2) the Gini coefficient is added and income inequality has a negative and significant coefficient. When fertility is introduced in the model (Regression 3), income inequality has a positive and insignificant effect on growth but fertility has a negative and significant effect. Finally, once differential fertility is added as explanatory variable

a long time-as seems to be true empirically-then the growth effect of a variable lasts for a long time. Additionally, DLCD predict that by introducing idiosyncratic ability shocks in the production function for human capital, there is inequality among households even in the long run.

[5]Detailed description of the data is provided in the published paper of De La Croix and Doepke and our appendix.

(Regression 4), its negative and significant coefficient rules out any interpreting role that inequality and fertility had. Income inequality again has the wrong sign. The insignificance of the Gini and fertility is opposing the predictions of the theoretical model of DLCD according to which the Gini, total fertility and differential fertility should all be negatively linked to growth.

To corroborate the estimation results and further strengthen their argument about differential fertility's significance, the authors employ a quasi Likelihood Ratio test. This is the D-test introduced by Newey and West (1987) and is a GMM counterpart to the classical LR test. It is defined as the normalized difference of the restricted and unrestricted objective functions for the efficient GMM estimator. The weighting matrix used in the estimation of both the restricted and the unrestricted estimators is computed by the use of the unrestricted estimator, which is consistent under both $H_0$ and $H_1$. It is distributed as $\chi^2$ with $\nu$ degrees of freedom, where $\nu$ is the number of restrictions. $LR_1$ tests the absence of differential fertility in the equation. It validates DLCD assertions since the null is rejected and DTFR seems to be significant. $LR_2$ tests the absence of both the Gini and fertility in the equation and its results comes in accordance with their individual t-statistics since the null hypothesis of their joint insignificance is not rejected.

DLCD report Hansen's J-test, which is a test of over-identifying restrictions. The joint null hypothesis is that the included instruments are valid, i.e. uncorrelated with the error, and that the specification of the structural equation is valid. The validity of the instrument set is verified since the null hypothesis is never rejected at the 5% level. The p-value of the test is greatly increased once differential fertility is included in the regression.

De La Croix and Doepke's results are interesting but the important question is whether they are robust. The first concern is with their results. A closer look at the estimates of the J-tests raises some considerations triggered by the p-values reported in brackets. The J-statistic is distributed as $\chi^2$ with degrees of freedom equal to the number of overidentifing restrictions $(L - K)$ rather than the total number of moment conditions $L$. The p-values which DLCD mention correspond to 18, 17, 16 and 15 degrees of freedom for regressions (1) to (4) respectively. This seems unreasonable since the instruments they mention are just twelve. These p-values correspond to twenty-two instruments. Working out the p-values for 7, 6, 5 and 4 degrees of freedom they are 0.013, 0.007, 0.005 and 0.048. The null hypothesis is thus rejected for all equations, suggesting invalidity of the instrument set.

An additional concern is the use of squared values of the explanatory variables as instruments. Using the squares of the RHS variables as instruments is not uncommon in applied econometrics since their employment captures any possible non-linear effects between the RHS variables and the independent variable and hence the fit of the regression improves. However, the correlation between the $lnGDP$ and $(lnGDP)^2$ is 0.998 whereas for $lnTFR$ and $(lnTFR)^2$ it is 0.994, both statistically significant at 5% level. These correlations are so high that they almost amount to instrumenting endogenous variables with themselves.

We tried to replicate the results of DLCD. The outcome was awkward since we had problems in replicating even the descriptive statistics table (Table 3). At their descriptive statistics table, they report the minimum average growth rate as -5.75%, implying that a country experienced a fall in GDP per capita of 61% between 1960 and 1976. However, according to Penn World Table 6.1, there is no country which has experienced such a fall. Confusingly the data set provided by Pr. De La Croix did not have such an observation. Similarly, differences appear in the mean and standard deviation of TFR for the first period. Obviously, these differences affect the relevant descriptive statistics for the total sample size too.

We re-estimated the above regressions using De La Croix and Doepke's data and the information given in the paper about the exact estimation procedure. Table 4 exhibits the outcome. The estimates are very similar for regressions (1) and (2) with minor deviations of the values but similar signs and significance. However, in regression (3) when the problematic TFR is introduced, occasional deviations appear. The average ratios of investment to GDP, average ratio of government expenditure to GDP and initial total fertility ratio have correct signs but are not significant , contrary to what DLCD mention.[6] Regression (4) is characterized by similar differences. The signs of all the variables are consistent but the average ratios of investment to GDP, average ratio of government expenditure to GDP and differential fertility, with the importance of the latter being the corner stone of De La Croix and Doepke's analysis, are not significant. According to the Hansen's J-test, the instruments do satisfy the orthogonality conditions required for their employment. The p-value of the test improves once total initial fertility is introduced but the inclusion of differential fertility doesn't strengthen the validity of the instrument set, contrary to the findings of DLCD. $LR_1$ and $LR_2$ tests establish the insignificance of TFR, DTFR and Gini, symmetrically to individual t-ratios.

The unreasonable degrees of freedom apparently used for the J-test raised concerns whether there was an imprecise description of the instruments used in the published paper. In that case the different results we got during the replication might be explained. Since the reported p-values correspond to twenty-two instruments we interacted all instruments with the period dummies. We re-estimated the regressions of DLCD and the results are now almost identical with the ones presented in the published paper (see Table 5). What is of highest importance is that the coefficient of differential fertility is significant. Thus, apparently, the authors allowed for a "structural break" in the first stage regression. Although, the ideal number of instruments is an "uncharted sea", twenty two instruments would probably be too high a number.

The obvious next step is to check the data they provided us. We compared all observations with the original source and recalculated all the average rates. The details of the alterations made are left for the documentation appendix but some major comments should be made here. Due to occasional inappropriate correspondence, usually in terms of time, of employed data with the declared definition of the vari-

[6]The insignificance of I/GDP and G/GDP is not a common fact in growth regressions. Sala-I-Martin (1997) identifies "robust" empirical relations in the economic growth literature and classifies investment in one of the 22 out of 59 variables that appear to be "significantly" correlated with growth, although government spending does not affect growth, at least not in the linear way that he specifies.

ables, the number of observations falls to 68 from the original 83. The inappropriate time correspondence issue mainly refers to Gini observations, which according to the authors correspond to the initial year or the closest available year.[7] Some examples are Romania's observation for the period 1960-1976 is from 1989, Ghana's from 1988, Jordan's from 1980, Paraguay's from 1983, and Burkina Faso's whose observation for the period 1976-1992 seems to come from 1995. Some problems are also detected in the dummy for African countries with e.g. Botswana and Sudan not defined as African countries as well as with the access to the sea variable with e.g. Botswana or Mali not included in the countries that have access to the sea.[8]

Table 6 provides descriptive statistics for the main variables of this new data set which largely uses the same sources as DLCD. The values are much alike the ones reported in the previous tables with no great deviations for all variables. Table 7 gives the estimation results. We use eleven instruments only and we allow for correlation in the errors across the two different growth periods and thus we cluster by country. Regressions (1) and (2) reproduce similar results with De La Croix and Doepke's estimates. However, regression (3) draws a different picture. The introduction of total initial fertility doesn't reduce the explanatory power of the Gini coefficient which remains significant at 5% level (actually the negative effect of income inequality on growth increases). This result opposes the (empirical) findings of DLCD as well as Barro (2000) and might signal the absence of significant borrowing constraints which would otherwise prevent families with many children from investing in human capital.[9] The coefficient of the Gini is -0.11, which implies that an increase of one standard deviation in the Gini coefficient decreases growth by 1.03 percentage points, an economically significant result (the mean growth for 1960-1992 is 1.88). Contrary

[7] De La Croix and Doepke, (2003), p.1106.

[8] The definition of the variable ACCESS from Sachs and Warner (1997), the original source of the data, is "Physical access to international waters is measured by our land-locked variable. A country that borders the ocean (a "coastal economy") and that has a container port is given a value of 0, reflecting complete access to international shipping. A landlocked country without navigable access to the sea via rivers is given a value of 1". The ACCESS for Botswana and Mali has a value of 1.

[9] The 11 countries we had to drop from the sample compared to De La Croix and Doepke are mainly developing ones. Since the absence of significant borrowing constraints is a characteristic of developed rather than developing countries, the change of the relative weight of developing and developed countries in the sample might explain the different finding.

to DLCD results, the log of initial GDP, the dummy for African countries and the newly introduced total fertility seem to have no significance. Moreover, fertility is positively linked to growth, a finding that violates both the theoretical and empirical predictions of DLCD.

Regression (4) is the important regression since differential fertility variable is included. The coefficient of differential fertility is negative and significant, although only at the 10% level, which is verified by the $LR_1$ test. An increase of one standard deviation in its coefficient lowers growth by 1.6 percentage points. The coefficient of the Gini is now smaller and has the correct sign but it is insignificant. Growth is significantly and positively related to TFR. However, according to the $LR_2$ test, the joint insignificance of the Gini and total fertility cannot be rejected. The reason for the change in the significance of inequality and total fertility caused by the inclusion of differential fertility in the regression is not clear. It is maybe a case akin to De La Croix and Doepke's exegesis for a similar result that total fertility and inequality have other effects on growth that are not present in the model, a fact that is altered once differential fertility is included.

DLCD measure Differential Fertility as the difference in the total fertility rate between women with the highest and the lowest education level. By doing so the results may be unreliable since the percentage of the women belonging in these categories is not taken into consideration. There are countries that are characterized by rather unequal distributions, such as Bangladesh, which has 78% of women in the lowest education category and 1% in the highest or Yemen with 98% and 0% respectively, and other that are characterized by a more uniform distribution such as Peru, Sri Lanka or Mexico where each of the five different educational categories contains from 10% to 30% approximately of the women's population. Since basing a variable on 0% of the population is unsatisfactory, we employed a different measure for differential fertility. This new variable is the weighted least squares measure of differential fertility (Wtd-DTFR) used by Kremer and Chen (2002). They approximate differential fertility as the coefficient from the weighted least squares regression of ln(TFR) on years of education, where observations are weighted by the percentage of women in the education category.[10] Weighting observations reduces the noise with which fertility is measured at, especially, the extreme levels of educational attainment. The correlation between DTFR and Wtd-DTFR is 0.73 (significant at the 5% level), low enough to characterize them as similar but not identical measures.

Regression (5) is identical to Regression (4) apart from using Kremer and Chen's measure for differential fertility. The original data sources are common in these two different measures and the differences are hence interesting. Including differential fertility in a standard growth regression does not weaken the negative relationship between inequality and growth as DLCD found. More specifically, the Gini coefficient is significant, has the correct sign and the negative relationship between inequality and growth not only isn't weakening, but is now getting stronger. Total Fertility and Differential Fertility have no explanatory power for growth. Moreover, the measure of differential fertility is now positively linked to growth and a change of one standard deviation in Wtd-DTFR increases growth by 1.29 percentage points. The Likelihood Ratio test verifies the above results since the null cannot be rejected for Wtd-DTFR according to the $LR_1$ test whereas the joint insignificance of GINI and TFR is rejected.

We employ a weak identification test to control for the correlation between the instruments and the endogenous regressors. This test uses the F-statistic of the first stage regression. Stock and Yogo (2005) provide the critical values to which the F-statistic should compare. Unfortunately, the critical values are calculated for a maximum of three endogenous regressors. For a greater number of endogenous regressors we follow a rule-of-thumb which suggests that an instrument is weak if the F-statistic of the first stage regression is less than 10. The values of the test suggests that the instruments used are weak in all regressions.

Checking the individual t-tests of the first stage regression can also give some suggestive information about the two critical instruments i.e. the log of initial GDP

[10] Their data are from four comparative studies (United Nations 1987, Jones 1982, United Nations 1995 and Mboup and Saha 1998) and are the same with those that De La Croix and Doepke use. Note that the percentage distribution of women is only available for data from UN.

per capita squared and initial fertility squared. The two instruments which are the squared values of the explanatory variables are never important statistically.[11]

Hansen's J-tests indicates that the null is rejected for all five regressions except for Regression (4). The instruments, hence, seem to be incorrectly excluded from the regression. One explanation could be the existence of nonlinear effects between the level of development and inequality to growth rates in line with Barro (2000) and Banerjee and Duflo (2003). Since some of the excluded instruments are the squares of the RHS variables, the value of the J-test may signify the need to include them in the regression. However, it is not clear why the same set of instruments seems to be valid in Regression (4).

It is obvious that there is a problem in the chain between inequality, differential fertility and growth. We check whether the first part of this chain, from inequality to differential fertility, is problematic (rather than the second, which DLCD examine). Kremer and Chen (2002) show that the fertility differential between the educated and non-educated women is greater in less equal countries. Moreover, we estimated regressions with differential fertility as the dependent variable and use various specifications. Our results are qualitatively similar and verify Kremer and Chen's arguments (Table 8). So, having ruled out the possibility of a weak link between inequality and differential fertility, it seems that differential fertility is not a transmission mechanism from inequality to growth. Instead inequality affects growth directly and/or through channels other than differential fertility.

Another matter for consideration is the estimation method.[12] GMM estimators are consistent but biased and only asymptotically normal and the finite sample properties of GMM estimators are not fully understood. DLCD have a sample size of 83 observations, critical enough to justify an indubitable use of GMM and even more critical for the smaller data set we use. In order to check the robustness of our results

[11] Actually, the null cannot be rejected for most of the instruments.

[12] Benhabib and Spiegel (1998), Li and Zou (1998) and Forbes (2000), all look at the relationship between growth and inequality using fixed effects estimates, arguing that there are omitted country specific effects that cause a bias. However, countries' fixed effects cannot be used here due to the small sample size since only 11 countries have observations for both periods.

we re-estimate the above regressions by using Instrumental Variables (IV), which is a special case of GMM. IV needs a "large" sample size too since it has similar small and large sample properties to GMM. And although it does not have the efficiency gains that GMM acquires by the use of optimal weighting matrix and the relaxation of the i.i.d. assumption, if IV reproduces similar results to GMM it will signal a greater soundness of our arguments. Table 9 provides the estimation results of the same five regressions when IV is employed. The three first regressions have no important differences from the GMM estimates. Gini is always significant except for the case that DTFR is included, plus now the fact that both measures of differential fertility are insignificant (the difference in the signs of the two measures is present here too).

## 4.3 Further Discussion of Problems with the Data: Some Cross-Section Results

There are two major problems with the data that call for further discussion. The first one refers to the choice of the periods used and more specifically to the inclusion of the years 1973-1976 in the first period; the second problem is the time correspondence of the differential fertility data. We check the consequences of these two problems by forming two new data sets and doing a cross sectional analysis.

The inclusion of the years after 1973's oil shock in the first period can result in misleading conclusions since there were significant effects for world economies which lingered on throughout 70s. We estimate the above regressions for a shorter first period leaving out the years from 1973 to 1976. The correlation between the growth rate of 1960-1973 and the growth rate of 1960-1976 is 0.947. Table 10 gives the descriptive statistics and Table 11 gives the results of the GMM estimation for this cross sectional estimation. The information we get from this cross-section data set is rather poor. The most robust result is the significant and positive coefficient of I/GDP, a common fact in growth regressions (IV and OLS estimation-Tables 12 and 13 respectively- give similar results). Differential fertility is not significant and the coefficient of Wtd-DTFR is still positive. J-test gives credit to the instruments used and the p-value is much higher in Regression (5) compared to the other four regressions. However, instruments are weak and the null cannot be reject for $(lnGDP)^2$ and $(lnTFR)^2$ in the first stage regression..

Looking at the critical variable of De La Croix and Doepke's model, namely at differential fertility, we notice that the year that the observations are supposed to describe and the year they are from are not compatible. For the early period (1960-1976), 24 out of 40 observations belong to years after the period. More specifically, 24 observations come from 1977-1982 and the remaining 16 come from 1974-1976. For the period 1976-1992 the representation is slightly better. The surveys used give data for 1985-1989 and 1990-1994 with 10 observations out of 43 coming from years later than 1992. DLCD comment, "...the observations on fertility differentials are close to the end of the period over which we compute the growth rates. Since the fertility observations are five year averages and result from decisions and actions taken earlier, the endogeneity problem is not too severe. We correct for potential endogeneity of the differentials by using instrumental variables".[13] However, because 40% of the data come from years out the period of interest and the rest correspond to the end we estimate the above regressions as a cross-section for the second period only but using the differential fertility observations of the first period.

Table 14 provides the descriptive statistics for this new data set. The sample size is constrained by the availability of the data, mainly of DTFR. We complete the data set using the same sources and the same procedures for all the calculations as earlier. Table 15 provides the estimation results. Inequality has no explanatory power in all four regressions. Differential fertility is significant when measured by either DTFR or Wtd-DTFR. Moreover, both measures are negatively linked to growth, contrary to previous findings. The weak identification test implies that the instruments are weak in all specifications. An interesting result is the evolution of the p-value of the J-test; it is much higher for the fourth and fifth regression, which gives a direction for further research, especially because there was a similar result for the 1960-1973 when

[13] De La Croix and Doepke, (2003), p.1106.

Wtd-DTFR was introduced. Moreover, $(lnGDP)^2$ and $(lnTFR)^2$ are statistically insignificant in the first stage regression.

Estimation with IV (Table 16) draws a similar picture to GMM but Gini and Wtd-DTFR are now significant at 10% in Regression (5). OLS give totally different results with I/GDP and initial GDP being the only robustly significant determinants of growth for all five regressions (Table 17).

Summarizing the information we get from these two cross-sectional data sets, there is one thing we can argue with confidence: there is a problem of robustness. The three different econometric techniques used to estimate the same regressions give different findings, a result not really unexpected, and create a rather cloudy picture. Inequality is not linked to growth and the evidence for the differential fertility is inconclusive.

## 4.4 The Appropriate Measure of Inequality

The theoretical model of DLCD predicts that inequality in human capital leads to inequality in education and a differential fertility effect -more children provided with lower education- that lowers future average human capital and hence lowers growth. In spite of the distribution of human capital being the relevant source of inequality, DLCD use income inequality data to proxy it. This approach is probably a compromise forced by the data availability (the majority of the relevant surveys are actually performed using the income inequality data provided by Deininger and Squire (1996)). Castello and Domenech (2002) exploited the updated information which Barro and Lee (2001) provide about educational attainments and calculate a human capital Gini coefficient. Surprisingly, they find that there is a low correlation between the human capital and the income Gini coefficient (0.27). Motivated by such a finding, we use the data for human capital Gini to check whether the invalidation of differential fertility as a transmitting mechanism between inequality and growth accrues from a mistaken proxy used for inequality.

The low correlation that Castello and Domenech (2002) mention between the two inequality indicators is verified for our sample too. The correlation, shown in Figure 1, is negligible (–0.063) and even carries a negative sign.

Table 18 shows the descriptive statistics of the data set and Table 19 gives the estimation results. The four equations are identical to the former Regressions (2), (3), (4) and (5) but now the human capital Gini coefficient (HC GINI) is used instead of the income Gini. We keep instrumenting the HC Gini coefficient to correct for possible endogeneity. Regression (2) reproduces similar results to the case when the income Gini is used. The human capital inequality appears to be significant for growth, similarly to the case of the income Gini. At Regression (3) the results are consistent with our earlier findings when fertility is introduced. The coefficient on the HC Gini retains the correct sign and significance whereas fertility is significant but only at the 10% level, contrary to the predictions of DLCD. Including the critical variable of differential fertility doesn't bring any surprises. Regression (4) suggests that growth is not related to human capital inequality but it is related to DTFR. An increase of one standard deviation in DTFR coefficient decreases growth by 2.07 percentage points. Regression (5) suggests that human capital inequality is significant, and the increase of one standard deviation decreases growth by 1.39 percentage points. Wtd-DTFR is insignificant and the increase of one standard deviation in Wtd-DTFR decreases growth by 1.95 percentage points. However, both measures of differential fertility now suggest that the link between differential fertility and growth is negative. Hansen's test validates the instrument set only when differential fertility is included as a RHS variable but the instruments are weak. Moreover, the critical instruments $(lnGDP)^2$ and $(lnTFR)^2$ are insignificant in the first stage regression.

Using these human capital inequality data , we do three more robustness checks. First, we estimate the panel by IV; second, we estimate the cross section version using the above "time correspondence improved data set" on differential fertility; and third, we estimate a more general form of the above regressions for the panel.

The IV estimations (Table 20) reproduces the main facts of the GMM estimation with respect to differential fertility. The negative signs of the coefficients of both measures are verified. DTFR gives credit to the differential fertility as a determinant of growth whereas Wtd-DTFR refutes it.

The cross-section estimation (Table 21) reproduces the qualitative findings of the cross-sectional estimation in the case that the income Gini is used. However, compared to the panel estimation, only the crucial fact of differential fertility's lack of robustness as a transmitting mechanism between inequality and growth is reproduced. More analytically, HC Gini is never significant and initial total fertility is only significant when differential fertility is not included in the regression. Both measures of differential fertility imply that it has some explanatory power over growth at the 10% only level of significance. The negative signs of the coefficients of both measures are verified.

For the last check, we estimate a more general form of the above four regressions by introducing three extra variables relevant to the human capital nature of the model. The first variable is the human capital Gini, already used as an alternative to the income Gini. The second is the human capital accumulation rate, proxied by the average ratio of the total gross enrollment ratio in secondary education from Barro and Lee (2001). This is the counterpart to the physical capital accumulation rate I/GDP. We instrument it by the initial human capital accumulation rate to correct for possible endogeneity. The third variable is the human capital stock, proxied by the average of the total years for schooling of the population aged 15 and over from Barro and Lee (2001). There is a high and statistically significant correlation between human capital inequality and the stock of human capital (-0.8787) and it is possible that the former is picking up the effect of the latter on growth. We instrument it by the initial stock of human capital.[14] Finally, we follow Toya, Skidmore and Robertson (2004) and use natural disasters as an instrument for changes in schooling. We measure natural disasters as the "Logarithm of one plus the number of natural disaster events normalized by land area". We estimate various versions of this "general"

[14] We have tried using initial human capital stock both as an instrument and as a regressor.

specification, especially by trying different instrument sets (see Tables 22 (a), (b) and (c)). The significance of the regressors and the validation of the instrument set vary but there is a robust result: differential fertility is never significant, and this is unrelated to the choice of the index used to measure it.

Finally the results for the critical instruments, the log of initial GDP per capita squared and the initial fertility squared, do not change much when inequality is measured by human capital Gini. The t-statistics of the first stage regression suggest that the null cannot be rejected (although $(lnGDP)^2$ has some explanatory power for human capital stock or the human capital accumulation rate and $(lnTFR)^2$ for differential fertility).

## 4.5 Conclusions

In this paper we investigate the empirical relationship between income inequality and growth and challenge the empirical findings of De La Croix and Deopke (2003) who argue that the fertility-differential effect accounts for most of the empirical relationship between these two variables. The empirical evidence advanced here does not support that claim. Using panel data estimation we are unable to replicate their results and, on the contrary, we get strong evidence that differential fertility is not linked to growth. Using either a better measure of differential fertility than the one used by DLCD or a more general specification leads us to conclude that the significance of differential fertility is open to considerable doubt. The evidence on the explanatory power that human capital inequality has on growth is not so strong though. It is quite probable that there is a different channel other than inequality in education and the differential fertility effect that links inequality to growth. Further research is needed to reach a sound conclusion for the cross section case since although differential fertility and inequality seems to have no explanatory variable for growth, the samples used may be too small to give reliable results. Finally, finding instruments that are exogenous and also have high correlation with the instrumented variables is a challenge for future work.

## 4.6 Appendix
## TABLES

### Table 1 - Descriptive Statistics ofDe La Croix & Doepke Results

| Sample | Observations | Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| 1960-1976 | 40 | GR | 1.95 | 3.65 | -5.75 | 8.44 |
| | | GINI | 44.32 | 11.14 | 23.38 | 68.00 |
| | | TFR | 5.56 | 1.89 | 2.02 | 7.93 |
| | | DTFR | 2.23 | 1.56 | 0.22 | 5.30 |
| 1976-1992 | 43 | GR | 0.39 | 1.89 | -3.46 | 4.97 |
| | | GINI | 45.91 | 9.56 | 28.90 | 69.00 |
| | | TFR | 6.06 | 1.08 | 3.37 | 8.00 |
| | | DTFR | 2.41 | 0.99 | 0.10 | 4.50 |
| Total | 83 | GR | 1.14 | 2.97 | -5.75 | 8.44 |
| | | GINI | 45.14 | 10.32 | 23.38 | 69.00 |
| | | TFR | 5.82 | 1.54 | 2.02 | 8.00 |
| | | DTFR | 2.32 | 1.29 | 0.10 | 5.30 |

### Table 2- De La Croix & Doepke Regression Results

| Independent Variable | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Constant A | 12.35** (1.31) | 12.79** (1.33) | 15.30** (1.46) | 13.92** (1.69) |
| Constant B | 10.41** (1.36) | 10.98** (1.38) | 13.40** (1.45) | 12.18** (1.63) |
| Ln(GDP) | -1.33** (0.17) | -1.21** (0.16) | -1.37** (0.15) | -1.55** (0.20) |
| I/(GDP) | 0.14** (0.02) | 0.13** (0.02) | 0.07** (0.03) | 0.08** (0.04) |
| G/GDP | -0.08** (0.03) | -0.07** (0.03) | -0.05* (0.03) | -0.05* (0.03) |
| AFR | -1.75** (0.35) | -1.80** (0.35) | -1.95** (0.32) | -2.41** (0.44) |
| GINI | | -0.03** (0.01) | 0.02 (0.03) | 0.06 (0.05) |
| Ln(TFR) | | | -1.84** (0.87) | -1.01 (1.01) |
| Ln(DTFR) | | | | -1.22** (0.50) |
| J-test | 17.71 [0.48] | 17.11 [0.45] | 16.79 [0.40] | 9.58 [0.85] |
| $LR_1$ | | | | 5.53 [0.01] |
| $LR_2$ | | | | 2.08 [0.35] |

Notes: The dependent variable is the growth rate of real per capita GDP. Instruments and tests as described in the main text. Heteroskedasticity-consistent standard errors are reported in parentheses. J-test is the test for over-identifying restrictions of Hansen (1982), asymptotically $\chi^2$ distributed with n degrees of freedom, where n is the number of over-identifying restrictions. Corresponding p-values are reported in brackets. $LR_1$ is a quasi likelihood ratio test for the absence of the differential fertility in the equation. $LR_2$ is the test for the absence of both Gini and total fertility. The statistics are computed as the normalized difference between the constrained objective function and the unconstrained one (see Gallant (1987)). The constrained estimation is computed with the weighting matrix provided by the unconstrained estimation. The corresponding p-values are reported in brackets. *Significant at the 10 % level. ** Significant at the 5 % level.

**Table 3 – Replication Descriptive Statistics**

| Sample | Observations | Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| 1960-1976 | 40 | GR | 3.57 | 2.05 | -0.58 | 8.44 |
| | | GINI | 44.32 | 11.13 | 23.38 | 68 |
| | | TFR | 5.47 | 1.94 | 2.02 | 7.93 |
| | | DTFR | 2.23 | 1.56 | 0.22 | 5.3 |
| 1976-1992 | 43 | GR | 0.39 | 1.89 | -3.46 | 4.97 |
| | | GINI | 45.91 | 9.56 | 28.9 | 69 |
| | | TFR | 6.06 | 1.08 | 3.37 | 8 |
| | | DTFR | 2.41 | 0.99 | 0.10 | 4.5 |
| Total | 83 | GR | 1.92 | 2.53 | -3.46 | 8.44 |
| | | GINI | 45.14 | 10.32 | 23.38 | 69 |
| | | TFR | 5.77 | 1.57 | 2.02 | 8 |
| | | DTFR | 2.32 | 1.29 | 0.1 | 5.3 |

**Table 4**

**Regression- De La Croix & Doepke Data**

| Independent Variable | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Constant A | 12.11** (1.37) | 13.13** (1.52) | 18.60** (4.04) | 14.80** (6.82) |
| Constant B | 10.04** (1.46) | 10.95** (1.58) | 16.46** 4.00) | 12.84* (6.59) |
| Ln(GDP) | -1.31** (0.19) | -1.09** (0.21) | -1.84** (0.54) | -1.61** (0.65) |
| I/(GDP) | 0.14** (0.03) | 0.09** (0.03) | 0.03 (0.07) | 0.04 (0.07) |
| G/GDP | -0.06** (0.03) | -0.06* (0.03) | -0.01 (0.07) | -0.03 (0.08) |
| AFR | -2.01** (0.42) | -2.01** (0.44) | -2.55** (0.78) | -2.73** (0.78) |
| GINI | | -0.04** (0.02) | 0.13 (0.12) | 0.11 (0.13) |
| Ln(TFR) | | | -4.61 (3.19) | -2.23 (4.72) |
| Ln(DTFR) | | | | -1.07 (1.45) |
| J-test | 13.55 [0.06] | 10.99 [0.09] | 4.63 [0.46] | 4.92 [0.30] |
| $LR_1$ | | | | 1.69 [0.19] |
| $LR_2$ | | | | 0.63 [0.73] |

Notes: The dependent variable is the growth rate of real per capita GDP. Estimation by GMM. Instruments and test statistics as described in the main text. Heteroskedasticity-consistent standard errors are reported in parentheses.

*Significant at the 10 % level.

** Significant at the 5 % level.

**Table 5**

**Regression- De La Croix & Doepke Data but with 22 instruments**

| Independent Variable | (1) | | (2) | | (3) | | (4) | |
|---|---|---|---|---|---|---|---|---|
| Constant A | 12.05** | (1.22) | 12.78** | (1.41) | 14.85** | (1.49) | 14.00** | (1.49) |
| Constant B | -1.82** | (0.32) | -1.79** | (0.32) | -1.86** | (0.32) | -1.71** | (0.35) |
| Ln(GDP) | -1.31** | (0.16) | -1.13** | (0.17) | -1.31** | (0.15) | -1.50** | (0.16) |
| I/(GDP) | 0.14** | (0.02) | 0.11** | (0.03) | 0.08** | (0.04) | 0.08** | (0.04) |
| G/GDP | -0.08** | (0.03) | -0.06** | (0.03) | -0.05 | (0.03) | -0.04 | (0.03) |
| AFR | -1.92** | (0.39) | -1.96** | (0.41) | -2.18** | (0.41) | -2.54** | ( 0.44) |
| GINI | | | -0.04** | (0.01) | -0.00 | (0.03) | 0.05 | (0.04) |
| Ln(TFR) | | | | | -1.33 | (0.93) | -0.92 | (0.99) |
| Ln(DTFR) | | | | | | | -1.00** | (0.44) |
| J-test | 23.27 | [0.18] | 18.47 | [0.36] | 17.14 | [0.38] | 13.572 | [0.56] |
| $LR_1$ | | | | | | | 6.26 | [0.01] |
| $LR_2$ | | | | | | | 2.01 | [0.37] |

Notes: The dependent variable is the growth rate of real per capita GDP. Estimation by GMM. The eleven instruments previously used are interacted with each period dummy. Test statistics as described in the main text. Heteroskedasticity-consistent standard errors are reported in parentheses.

*Significant at the 10 % level.

** Significant at the 5 % level.

**Table 6 – Re-collected Data Descriptive Statistics**

| Sample | Observations | Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| 1960-1976 | 32 | GR | 2.99 | 1.87 | -0.63 | 8.05 |
| | | GINI | 45.86 | 11.28 | 25.30 | 75.82 |
| | | TFR | 5.57 | 1.84 | 2.41 | 7.93 |
| | | DTFR | 2.27 | 1.52 | 0.22 | 5.10 |
| 1976-1992 | 36 | GR | 0.88 | 2.05 | -2.64 | 5.66 |
| | | GINI | 45.10 | 7.48 | 28.9 | 60.29 |
| | | TFR | 5.95 | 1.15 | 3.37 | 8 |
| | | DTFR | 2.32 | 1.08 | 0.10 | 4.5 |
| Total | 68 | GR | 1.88 | 2.22 | -2.64 | 8.05 |
| | | GINI | 45.46 | 9.39 | 25.3 | 75.82 |
| | | TFR | 5.77 | 1.52 | 2.41 | 8 |
| | | DTFR | 2.30 | 1.30 | 0.1 | 5.1 |

**Table 7**

**Regressions – Re-collected Data**

| | (1) | | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Constant_A** | 6.59** | (2.29) | 11.75** | (2.45) | 6.56 | (4.21) | -3.93 | (8.34) | 10.98 | (10.02) |
| **Constant_B** | -0.85** | (0.42) | -0.86** | (0.39) | -0.92** | (0.39) | -0.91** | (0.41) | -1.27** | (0.49) |
| **lnGDP** | -0.67** | (0.33) | -0.95** | (0.31) | -0.49 | (0.44) | 0.04 | (0.62) | -0.72 | (0.87) |
| **I/GDP** | 0.12** | (0.03) | 0.14** | (0.03) | 0.17** | (0.04) | 0.14** | (0.05) | 0.17** | (0.05) |
| **G/GDP** | -0.04* | (0.02) | -0.04** | (0.02) | -0.04** | (0.02) | -0.04 | (0.03) | -0.03 | (0.03) |
| **AFR** | -1.01** | (0.51) | -1.15** | (0.54) | -0.91 | (0.58) | -1.27* | (0.71) | 0.77 | (0.83) |
| **GINI** | | | -0.07** | (0.02) | -0.11** | (0.04) | -0.06 | (0.06) | -0.16** | (0.04) |
| **lnTFR** | | | | | 1.64 | (1.23) | 4.88** | (2.48) | -0.03 | (2.94) |
| **lnDTFR** | | | | | | | -2.05* | (1.17) | | |
| **Wtd_DTFR** | | | | | | | | | 36.82 | (29.91) |
| **N** | 68 | | 68 | | 68 | | 68 | | 68 | |
| **Weak ID test** | 17.03 | | 5.74 | | 2.00 | | 0.60 | | 0.37 | |
| **J-test** | 14.81 | [0.04] | 15.55 | [0.02] | 13.49 | [0.02] | 8.17 | [0.09] | 9.64 | [0.047] |
| **$LR_1$** | | | | | | | 3.06 | [0.08] | 1.52 | [0.22] |
| **$LR_2$** | | | | | | | 4.78 | [0.09] | 15.59 | [0.00] |

Notes: The dependent variable is the growth rate of real per capita GDP. Estimation by GMM. Standard errors are clustered by country. Heteroskedasticity-consistent standard errors are reported in parentheses. Instruments and test statistics as described in the main text. *Significant at the 10 % level., ** Significant at the 5 % level.

**Table 8- Differential Fertility-Inequality**

| | DTFR | | | | Wtd-DTFR | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| **Constant** | -1.13** | -2.82** | 0.08 | -2.30** | -0.02 | -0.04* | 0.07** | -0.01 |
| | (0.38) | (0.45) | (0.27) | (0.47) | (0.02) | (0.02) | (0.01) | (0.02) |
| **GINI** | 0.04** | 0.03** | | | 0.00** | 0.00** | | |
| | (0.01) | (0.01) | | | (0.00) | (0.00) | | |
| **lnTFR** | | 1.33** | | 1.89** | | 0.01 | | 0.06** |
| | | (0.23) | | (0.32) | | (0.01) | | (0.02) |
| **HC_GINI** | | | 0.01** | -0.01 | | | -0.00 | -0.00** |
| | | | (0.00) | (0.00) | | | (0.00) | (0.00) |
| N | 68 | 68 | 69 | 69 | 68 | 68 | 69 | 69 |

Notes: The dependent variable is DTFR for columns (1) to (4) and Wtd-DTFR for columns (5) to (8). Estimation by OLS. Standard errors are clustered by country. Heteroskedasticity-consistent standard errors are reported in parentheses.
* Significant at the 10% level., ** Significant at the 5% level.

**Table 9**

**Regressions – Re-collected Data**

| | (1) | | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Constant_A** | 7.95** | (2.60) | 11.25** | (3.06) | 8.58* | (4.56) | -2.42 | (8.50) | 20.90* | (10.88) |
| **Constant_B** | -0.76* | (0.44) | -0.83** | (0.41) | -0.79* | (0.40) | -0.69 | (0.42) | -0.80 | (0.52) |
| **lnGDP** | -0.89** | (0.35) | -0.83** | (0.35) | -0.60 | (0.47) | -0.00 | (0.63) | -1.62* | (0.94) |
| **I/GDP** | 0.14** | (0.04) | 0.15** | (0.03) | 0.16** | (0.04) | 0.15** | (0.05) | 0.17** | (0.05) |
| **G/GDP** | -0.04** | (0.02) | -0.04* | (0.02) | -0.04* | (0.02) | -0.04 | (0.03) | -0.02 | (0.03) |
| **AFR** | -0.70 | (0.56) | -0.60 | (0.58) | -0.58 | (0.59) | -0.94 | (0.74) | 0.87 | (0.85) |
| **GINI** | | | -0.09** | (0.03) | -0.11** | (0.05) | -0.08 | (0.07) | -0.16** | (0.04) |
| **lnTFR** | | | | | 1.04 | (1.39) | 4.59* | (2.51) | -2.52 | (3.17) |
| **lnDTFR** | | | | | | | -1.85 | (1.19) | | |
| **Wtd_DTFR** | | | | | | | | | 49.80 | (31.64) |
| N | 68 | | 68 | | 68 | | 68 | | 68 | |

Notes: The dependent variable is the growth rate of real per capita GDP. Estimation by IV. Standard errors are clustered by country. Heteroskedasticity-consistent standard errors are reported in parentheses. Instruments and test statistics as described in the main text. *Significant at the 10 % level. ** Significant at the 5 % level.

**Table 10 - Descriptive Statistics**

**Cross-Section 1960-1973**

| Sample | Observations | Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| 1960-1973 | 31 | GR | 2.94 | 1.84 | -1.63 | 6.52 |
| | | GINI | 46.50 | 10.86 | 25.3 | 75.82 |
| | | TFR | 5.65 | 1.81 | 2.41 | 7.93 |
| | | DTFR | 2.30 | 1.53 | 0.22 | 5.1 |

**Table 11**

**Cross-Section 1960-1973**

| | (1) | | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Constant_A** | -0.50 | (3.17) | 2.83 | (4.21) | -5.46 | (6.52) | -9.48 | (13.75) | 49.34 | (61.56) |
| **lnGDP** | 0.27 | (0.32) | -0.14 | (0.42) | 0.45 | (0.55) | 0.25 | (0.64) | -3.55 | (4.62) |
| **I/GDP** | 0.05 | (0.03) | 0.10** | (0.05) | 0.16** | (0.06) | 0.13** | (0.06) | 0.33* | (0.18) |
| **G/GDP** | 0.03 | (0.07) | 0.04 | (0.07) | 0.07 | (0.08) | 0.20 | (0.21) | -0.47 | (0.60) |
| **AFR** | -0.20 | (1.02) | -0.73 | (1.13) | -0.19 | (1.16) | -1.02 | (1.42) | 7.03 | (6.29) |
| **GINI** | | | -0.02 | (0.03) | -0.06 | (0.04) | 0.01 | (0.08) | -0.36 | (0.31) |
| **lnTFR** | | | | | 2.08 | (1.31) | 3.69 | (3.68) | -8.69 | (12.32) |
| **lnDTFR** | | | | | | | -2.06 | (2.69) | | |
| **Wtd_DTFR** | | | | | | | | | 187.86 | (194.85) |
| **N** | 31 | | 31 | | 31 | | 31 | | 31 | |
| **Weak ID test** | 14.92 | | 7.31 | | 4.72 | | 0.21 | | 0.08 | |
| **J-test** | 7.61 | [0.27] | 8.69 | [0.12] | 6.56 | [0.16] | 6.75 | [0.08] | 0.30 | [0.96] |
| **$LR_1$** | | | | | | | 0.58 | [0.45] | 0.93 | [0.33] |
| **$LR_2$** | | | | | | | 0.95 | [0.62] | 1.70 | [0.43] |

Notes: The dependent variable is the growth rate of real per capita GDP. Estimation by GMM. Standard errors are clustered by country. Heteroskedasticity-consistent standard errors are reported in parentheses. Instruments and test statistics as described in the main text. *Significant at the 10 % level. ** Significant at the 5 % level.

**Table 12**

**Cross-Section 1960-1973**

| | (1) | | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Constant_A** | 2.03 | (4.45) | 6.56 | (5.37) | 5.48 | (8.09) | 1.18 | (15.00) | 47.40 | (68.02) |
| **lnGDP** | -0.15 | (0.43) | -0.53 | (0.49) | -0.45 | (0.66) | -0.38 | (0.71) | -3.41 | (5.04) |
| **I/GDP** | 0.10** | (0.05) | 0.15** | (0.05) | 0.16** | (0.06) | 0.14** | (0.07) | 0.30 | (0.20) |
| **G/GDP** | 0.01 | (0.10) | 0.07 | (0.10) | 0.07 | (0.10) | 0.14 | (0.23) | -0.45 | (0.69) |
| **AFR** | -0.24 | (1.30) | 0.09 | (1.25) | 0.13 | (1.24) | -0.21 | (1.48) | 6.16 | (7.45) |
| **GINI** | | | -0.07** | (0.03) | -0.08** | (0.04) | -0.04 | (0.09) | -0.33 | (0.36) |
| **lnTFR** | | | | | 0.37 | (1.59) | 1.73 | (3.81) | -8.21 | (13.65) |
| **lnDTFR** | | | | | | | -1.11 | (2.85) | | |
| **Wtd_DTFR** | | | | | | | | | 172.15 | (229.58) |
| **N** | 31 | | 31 | | 31 | | 31 | | 31 | |

Notes: The dependent variable is the growth rate of real per capita GDP. Estimation by IV. Standard errors are clustered by country. Heteroskedasticity-consistent standard errors are reported in parentheses. Instruments and test statistics as described in the main text. *Significant at the 10 % level. ** Significant at the 5 % level.

**Table 13**

**Cross-Section 1960-1973**

| | (1) | | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Constant_A** | 2.39 | (4.66) | 5.50 | (5.51) | 6.72 | (8.66) | 7.87 | (8.02) | 11.37 | (8.82) |
| **lnGDP** | -0.12 | (0.44) | -0.34 | (0.47) | -0.44 | (0.68) | -0.46 | (0.68) | -0.73 | (0.73) |
| **I/GDP** | 0.09* | (0.05) | 0.12** | (0.05) | 0.11* | (0.06) | 0.11* | (0.06) | 0.10* | (0.06) |
| **G/GDP** | -0.02 | (0.09) | 0.02 | (0.09) | 0.02 | (0.09) | 0.00 | (0.07) | -0.02 | (0.06) |
| **AFR** | -0.37 | (1.41) | -0.21 | (1.37) | -0.23 | (1.42) | -0.17 | (1.53) | 0.32 | (1.60) |
| **GINI** | | | -0.05* | (0.03) | -0.04 | (0.03) | -0.05 | (0.03) | -0.06 | (0.04) |
| **lnTFR** | | | | | -0.36 | (1.78) | -0.81 | (1.98) | -1.71 | (2.18) |
| **lnDTFR** | | | | | | | 0.26 | (0.71) | | |
| **Wtd_DTFR** | | | | | | | | | 17.69 | (14.12) |
| N | 31 | | 31 | | 31 | | 31 | | 31 | |

Notes: The dependent variable is the growth rate of real per capita GDP. Estimation by OLS. Standard errors are clustered by country. Heteroskedasticity-consistent standard errors are reported in parentheses. *Significant at the 10 % level. ** Significant at the 5 % level.

**Table 14 – Descriptive Statistics**

**Cross- Sectional 1976-1992**

| Sample | Observations | Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| 1976-1992 | 35 | GR | 1.15 | 1.67 | -2.31 | 6.42 |
| | 35 | GINI | 42.57 | 8.30 | 23.2 | 56.02 |
| | 35 | TFR | 4.74 | 1.97 | 1.69 | 8 |
| | 35 | DTFR | 2.32 | 1.60 | 0.22 | 5.3 |

**Table 15**

**Cross- Sectional 1976-1992**

| | (1) | | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Constant** | 7.90** | (2.91) | 8.79** | (2.76) | 16.62** | (4.92) | 12.18 | (8.79) | 9.98 | (8.26) |
| **lnGDP** | -1.10** | (0.42) | -0.96** | (0.40) | -1.51** | (0.54) | -1.48 | (0.90) | -1.25 | (0.83) |
| **I/GDP** | 0.18** | (0.06) | 0.15** | (0.07) | 0.07 | (0.06) | -0.04 | (0.08) | 0.04 | (0.08) |
| **G/GDP** | -0.02 | (0.01) | -0.01 | (0.02) | -0.01 | (0.01) | 0.04 | (0.03) | 0.00 | (0.02) |
| **AFR** | -1.01** | (0.41) | -1.00** | (0.41) | -1.68** | (0.59) | -3.88** | (1.39) | -4.61** | (1.54) |
| **GINI** | | | -0.04 | (0.03) | -0.01 | (0.04) | 0.08 | (0.07) | 0.13* | (0.08) |
| **lnTFR** | | | | | -1.95** | (0.99) | 0.13 | (2.25) | -0.51 | (1.66) |
| **lnDTFR** | | | | | | | -2.59** | (1.20) | | |
| **Wtd_DTFR** | | | | | | | | | -47.83** | (20.79) |
| **N** | 35 | | 35 | | 35 | | 35 | | 35 | |
| **Weak ID test** | 5.67 | | 2.28 | | 2.38 | | 0.89 | | 0.96 | |
| **J-test** | 12.53 | [0.08] | 11.96 | [0.06] | 11.03 | [0.051] | 1.52 | [0.82] | 2.27 | [0.69] |
| **$LR_1$** | | | | | | | 4.67 | [0.03] | 5.30 | [0.02] |
| **$LR_2$** | | | | | | | 1.34 | [0.51] | 2.89 | [0.24] |

Notes: The dependent variable is the growth rate of real per capita GDP. Estimation by GMM. Standard errors are clustered by country. Heteroskedasticity-consistent standard errors are reported in parentheses. Instruments and test statistics as described in the main text. *Significant at the 10 % level. ** Significant at the 5 % level.

Table 16

Cross- Sectional 1976-1992

| | (1) | | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Constant | 6.55* | (3.37) | 8.57** | (3.42) | 19.53** | (5.48) | 11.29 | (9.74) | 11.19 | (8.64) |
| lnGDP | -0.87* | (0.52) | -0.87* | (0.53) | -1.93** | (0.69) | -1.83* | (1.01) | -1.55* | (0.86) |
| I/GDP | 0.13 | (0.09) | 0.11 | (0.10) | 0.07 | (0.10) | 0.04 | (0.11) | 0.08 | (0.09) |
| G/GDP | -0.01 | (0.02) | 0.00 | (0.02) | 0.01 | (0.02) | 0.02 | (0.03) | 0.00 | (0.03) |
| AFR | -1.10* | (0.57) | -1.03* | (0.62) | -1.45** | (0.65) | -4.20** | (1.44) | -4.44** | (1.63) |
| GINI | | | -0.04 | (0.04) | 0.02 | (0.05) | 0.14 | (0.09) | 0.17** | (0.09) |
| lnTFR | | | | | -3.04** | (1.10) | 0.22 | (2.41) | -1.37 | (1.89) |
| lnDTFR | | | | | | | -2.95** | (1.33) | | |
| Wtd_DTFR | | | | | | | | | -47.67** | (23.30) |
| N | 35 | | 35 | | 35 | | 35 | | 35 | |

Notes: The dependent variable is the growth rate of real per capita GDP. Estimation by IV. Standard errors are clustered by country. Heteroskedasticity-consistent standard errors are reported in parentheses. Instruments and test statistics as described in the main text. *Significant at the 10 % level.. ** Significant at the 5 % level.

Table 17

Cross- Sectional 1976-1992

| | (1) | | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Constant | 7.87** | (3.14) | 7.90* | (3.95) | 17.92** | (5.92) | 17.86** | (6.53) | 17.00** | (6.49) |
| lnGDP | -1.12** | (0.44) | -1.12** | (0.45) | -2.02** | (0.55) | -2.01** | (0.57) | -1.94** | (0.59) |
| I/GDP | 0.17** | (0.06) | 0.17** | (0.06) | 0.14** | (0.06) | 0.14** | (0.06) | 0.14** | (0.06) |
| G/GDP | -0.01 | (0.02) | -0.01 | (0.01) | -0.00 | (0.02) | -0.00 | (0.02) | -0.00 | (0.02) |
| AFR | -0.97* | (0.55) | -0.97 | (0.59) | -1.24** | (0.57) | -1.26* | (0.74) | -1.54* | (0.78) |
| GINI | | | -0.00 | (0.04) | 0.03 | (0.04) | 0.03 | (0.05) | 0.04 | (0.04) |
| lnTFR | | | | | -2.42** | (1.06) | -2.39** | (1.17) | -2.18* | (1.10) |
| lnDTFR | | | | | | | -0.02 | (0.46) | | |
| Wtd_DTFR | | | | | | | | | -4.90 | (7.19) |
| N | 35 | | 35 | | 35 | | 35 | | 35 | |

Notes: The dependent variable is the growth rate of real per capita GDP. Estimation by OLS. Standard errors are clustered by country. Heteroskedasticity-consistent standard errors are reported in parentheses. *Significant at the 10 % level. ** Significant at the 5 % level.

Table 18 - Descriptive Statistics

Human Capital Gini

| Sample | Observations | Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|---|
| 1960-1976 | 34 | GR | 2.84 | 1.77 | -0.48 | 8.05 |
| | | HC GINI | 43.54 | 25.10 | 10.80 | 91.69 |
| | | TFR | 5.57 | 1.80 | 2.41 | 7.93 |
| | | DTFR | 2.33 | 1.62 | 0.22 | 5.3 |
| 1976-1992 | 35 | GR | 0.84 | 2.08 | -2.64 | 5.66 |
| | | HC GINI | 56.81 | 19.21 | 25.39 | 91.79 |
| | | TFR | 5.97 | 1.17 | 3.37 | 8 |
| | | DTFR | 2.37 | 1.09 | 0.1 | 4.5 |
| Total | 69 | GR | 1.82 | 2.17 | -2.64 | 8.05 |
| | | HC GINI | 50.27 | 23.12 | 10.80 | 91.79 |
| | | TFR | 5.77 | 1.52 | 2.41 | 8 |
| | | DTFR | 2.35 | 1.37 | 0.1 | 5.3 |

**Table 19**

**Regressions – Human Capital Gini**

| | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|
| **Constant_A** | 15.89** | (3.39) | 21.41** | (3.83) | -3.53 | (11.46) | 6.73 | (10.13) |
| **Constant_B** | -0.66* | (0.36) | -0.69* | (0.36) | -0.78* | (0.45) | -0.80 | (0.51) |
| **lnGDP** | -1.52** | (0.40) | -1.93** | (0.40) | -0.12 | (0.90) | -0.59 | (1.02) |
| **I/GDP** | 0.09** | (0.03) | 0.07** | (0.03) | 0.08* | (0.05) | 0.05 | (0.05) |
| **G/GDP** | -0.03 | (0.02) | -0.02 | (0.02) | -0.03 | (0.03) | -0.04 | (0.03) |
| **AFR** | -0.95* | (0.53) | -1.24** | (0.55) | -1.36 | (0.94) | -3.01** | (1.32) |
| **HC_GINI** | -0.05** | (0.01) | -0.05** | (0.01) | -0.03 | (0.03) | -0.06** | (0.02) |
| **lnTFR** | | | -1.25* | (0.73) | 5.32* | (3.02) | 3.87 | (3.14) |
| **lnDTFR** | | | | | -2.61** | (1.25) | | |
| **Wtd_DTFR** | | | | | | | -55.66 | (34.33) |
| **N** | 69 | | 69 | | 69 | | 69 | |
| **Weak ID test** | 8.52 | | 9.65 | | 1.40 | | 0.66 | |
| **J-test** | 14.20 | [0.03] | 13.97 | [0.02] | 5.08 | [0.28] | 6.46 | [0.17] |
| **$LR_1$** | | | | | 4.35 | [0.04] | 2.63 | [0.10] |
| **$LR_2$** | | | | | 5.21 | [0.07] | 7.01 | [0.03] |

Notes: The dependent variable is the growth rate of real per capita GDP. Estimation by GMM. Standard errors are clustered by country. Heteroskedasticity-consistent standard errors are reported in parentheses. Instruments and test statistics as described in the main text. *Significant at the 10 % level. ** Significant at the 5 % level.

**Table 20**

**Regressions – Human Capital Gini**

| | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|
| **Constant_A** | 13.32** | (3.63) | 17.58** | (4.11) | -4.91 | (12.11) | 3.98 | (11.02) |
| **Constant_B** | -0.71* | (0.38) | -0.77** | (0.38) | -0.64 | (0.52) | -0.76 | (0.51) |
| **lnGDP** | -1.29** | (0.43) | -1.53** | (0.42) | -0.01 | (0.95) | -0.27 | (1.09) |
| **I/GDP** | 0.09** | (0.03) | 0.08** | (0.03) | 0.09* | (0.05) | 0.07 | (0.05) |
| **G/GDP** | -0.03* | (0.02) | -0.03 | (0.02) | -0.04 | (0.03) | -0.05 | (0.03) |
| **AFR** | -0.82 | (0.61) | -0.95 | (0.63) | -1.41 | (0.94) | -2.55* | (1.38) |
| **HC_GINI** | -0.03** | (0.02) | -0.03* | (0.02) | -0.02 | (0.03) | -0.04 | (0.03) |
| **lnTFR** | | | -1.58** | (0.79) | 5.54* | (3.11) | 3.57 | (3.35) |
| **lnDTFR** | | | | | -2.90** | (1.28) | | |
| **Wtd_DTFR** | | | | | | | -54.05 | (36.02) |
| N | 69 | | 69 | | 69 | | 69 | |

Notes: The dependent variable is the growth rate of real per capita GDP. Estimation by IV. Standard errors are clustered by country. Heteroskedasticity-consistent standard errors are reported in parentheses. Instruments and test statistics as described in the main text. *Significant at the 10 % level. ** Significant at the 5 % level.

**Table 21**

**Cross-Section HC 1976-1992**

| | (1) | | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Constant** | 6.30** | (2.89) | 9.31** | (3.45) | 14.96** | (5.41) | 18.41* | (10.99) | 18.81* | (11.33) |
| **lnGDP** | -0.84** | (0.42) | -1.01** | (0.42) | -1.34** | (0.57) | -1.67 | (1.06) | -1.47 | (1.12) |
| **I/GDP** | 0.15** | (0.06) | 0.11 | (0.07) | 0.05 | (0.06) | -0.10 | (0.12) | -0.05 | (0.12) |
| **G/GDP** | -0.02** | (0.01) | -0.02** | (0.01) | 0.00 | (0.01) | 0.02 | (0.03) | -0.02 | (0.03) |
| **AFR** | -0.87* | (0.44) | -0.98** | (0.47) | -1.70** | (0.48) | -3.92** | (1.61) | -4.45** | (2.09) |
| **HC_GINI** | | | -0.02 | (0.01) | 0.01 | (0.02) | -0.07 | (0.05) | -0.10 | (0.07) |
| **lnTFR** | | | | | -2.41** | (0.82) | 2.13 | (3.58) | 2.75 | (3.78) |
| **lnDTFR** | | | | | | | -2.59* | (1.40) | | |
| **Wtd_DTFR** | | | | | | | | | -50.70* | (29.77) |
| **N** | 33 | | 33 | | 33 | | 33 | | 33 | |
| **Weak ID test** | 4.03 | | 6.60 | | 7.35 | | 0.70 | | 0.57 | |
| **J-test** | 12.24 | [0.09] | 11.14 | [0.08] | 10.59 | [0.06] | 0.37 | [0.99] | 0.88 | [0.93] |
| **$LR_1$** | | | | | | | 3.41 | [0.06] | 2.90 | [0.09] |
| **$LR_2$** | | | | | | | 2.05 | [0.36] | 3.12 | [0.21] |

Notes: The dependent variable is the growth rate of real per capita GDP. Estimation by GMM. Standard errors are clustered by country. Heteroskedasticity-consistent standard errors are reported in parentheses. Instruments and test statistics as described in the main text. *Significant at the 10 % level. ** Significant at the 5 % level.

Table 22 –General form

Table 22a - 3rd Regression

| | (1) | | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Constant_A | 19.88** | (3.83) | 6.51 | (5.12) | 13.61** | (5.74) | 8.10 | (4.95) | 8.83** | (4.01) |
| Constant_B | -0.54 | (0.35) | -0.47 | (0.38) | -3.48** | (1.11) | -0.54 | (0.36) | -1.65** | (0.47) |
| lnGDP | -1.71** | (0.39) | -0.06 | (0.52) | -1.04* | (0.56) | -0.32 | (0.49) | -0.28 | (0.41) |
| I/GDP | 0.08** | (0.03) | 0.21** | (0.05) | 0.11 | (0.06) | 0.20** | (0.05) | 0.15** | (0.05) |
| G/GDP | -0.02 | (0.02) | -0.04 | (0.02) | -0.02 | (0.04) | -0.05** | (0.02) | -0.02 | (0.03) |
| AFR | -1.35** | (0.56) | -0.61 | (0.63) | 0.08 | (0.79) | -1.02** | (0.49) | -0.04 | (0.62) |
| GINI | | | -0.15** | (0.03) | -0.07 | (0.06) | -0.14** | (0.03) | -0.13** | (0.03) |
| HC_GINI | -0.04** | (0.02) | -0.02 | (0.03) | -0.02 | (0.03) | -0.01 | (0.03) | -0.03 | (0.02) |
| HC_Acc_rate | -0.01 | (0.01) | -0.03 | (0.02) | -0.08** | (0.03) | -0.02 | (0.02) | -0.05** | (0.02) |
| lnTFR | -1.41* | (0.80) | 1.78* | (0.96) | -1.44 | (1.65) | 1.49 | (0.92) | 0.61 | (0.92) |
| HC | | | -0.20 | (0.37) | 11.54** | (3.36) | -0.14 | (0.36) | 4.87** | (1.37) |
| HC_ini | | | | | -10.93** | (3.16) | | | -4.80** | (1.27) |
| N | 69 | | 60 | | 60 | | 60 | | 60 | |
| Weak ID test | 9.54 | | 3.33 | | 0.57 | | 2.98 | | 2.64 | |
| J-test | 17.50 | [0.00] | 12.42 | [0.01] | 4.22 | [0.24] | 13.38 | [0.02] | 10.11 | [0.04] |

Table 22b – 4th Regression

| | (1) | | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Constant_A | -6.81 | (12.00) | -2.83 | (10.59) | -2.53 | (14.85) | 0.99 | (10.06) | -1.94 | (10.72) |
| Constant_B | -0.14 | (0.45) | -0.26 | (0.41) | -3.42** | (1.11) | -0.49 | (0.38) | -1.75** | (0.54) |
| lnGDP | 0.64 | (1.07) | 0.56 | (0.80) | 0.06 | (1.14) | 0.15 | (0.75) | 0.46 | (0.77) |
| I/GDP | 0.12** | (0.04) | 0.22** | (0.05) | 0.14** | (0.07) | 0.22** | (0.05) | 0.19** | (0.05) |
| G/GDP | -0.01 | (0.03) | -0.04 | (0.03) | -0.02 | (0.04) | -0.05** | (0.02) | -0.02 | (0.03) |
| AFR | -2.24** | (0.95) | -1.52* | (0.90) | -0.33 | (0.97) | -1.36* | (0.72) | -0.39 | (0.92) |
| GINI | | | -0.13** | (0.04) | -0.05 | (0.07) | -0.13** | (0.03) | -0.12** | (0.04) |
| HC_GINI | -0.03 | (0.03) | -0.00 | (0.04) | 0.00 | (0.04) | 0.01 | (0.03) | -0.01 | (0.03) |
| lnTFR | 4.74 | (2.92) | 3.91* | (2.28) | 2.28 | (3.65) | 2.84 | (1.92) | 2.95 | (2.58) |
| HC_Acc_rate | -0.07** | (0.03) | -0.07* | (0.04) | -0.13** | (0.05) | -0.05 | (0.04) | -0.09** | (0.04) |
| lnDTFR | -3.00** | (1.37) | -1.41 | (1.12) | -1.94 | (1.69) | -0.73 | (1.02) | -1.17 | (1.25) |
| HC | | | 0.13 | (0.49) | 12.25** | (3.55) | 0.08 | (0.45) | 5.43** | (1.54) |
| HC_ini | | | | | -11.34** | (3.34) | | | -5.06** | (1.41) |
| N | 69 | | 60 | | 60 | | 60 | | 60 | |
| Weak ID test | 0.77 | | 0.51 | | 0.66 | | 0.56 | | 0.56 | |
| J-test | 10.15 | [0.04] | 10.96 | [0.01] | 2.45 | [0.29] | 12.87 | [0.01] | 7.68 | [0.05] |

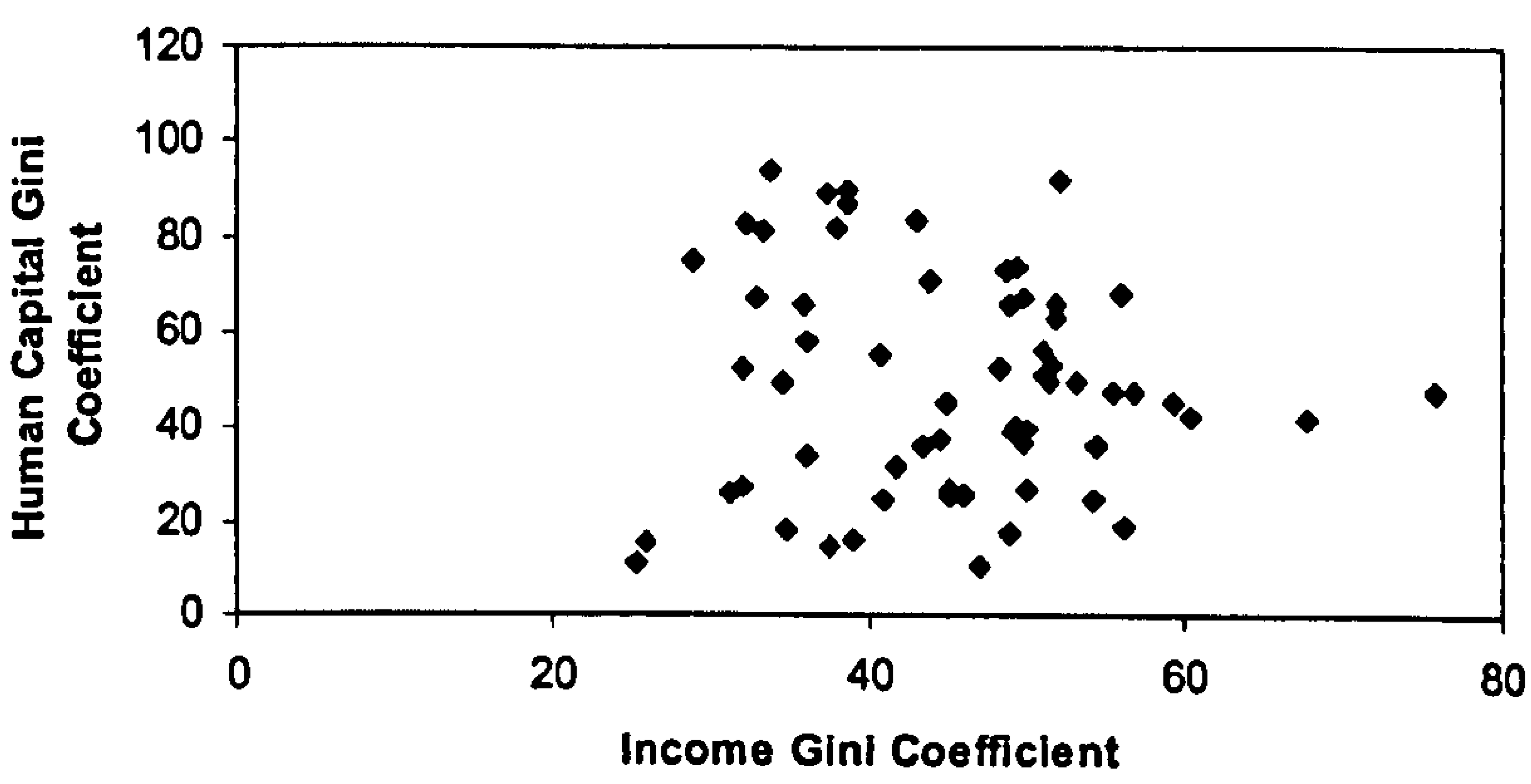
**Table 22c – 5th Regression**

| | (1) | | (2) | | (3) | | (4) | | (5) | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Constant_A** | 20.46** | (9.46) | 10.80 | (13.11) | 4.43 | (14.48) | 19.38* | (11.44) | 12.76 | (9.57) |
| **Constant_B** | -0.68* | (0.40) | -0.62 | (0.50) | -4.21** | (1.50) | -0.89* | (0.47) | -1.46** | (0.46) |
| **lnGDP** | -1.80* | (1.06) | -0.56 | (1.23) | -0.19 | (1.40) | -1.40 | (1.00) | -0.63 | (0.91) |
| **I/GDP** | 0.06** | (0.03) | 0.21** | (0.06) | 0.10 | (0.07) | 0.20** | (0.07) | 0.14** | (0.05) |
| **G/GDP** | -0.03 | (0.02) | -0.03 | (0.03) | -0.03 | (0.04) | -0.03 | (0.03) | -0.03 | (0.03) |
| **AFR** | -1.21 | (1.25) | 0.75 | (1.27) | -1.05 | (1.94) | 1.63 | (1.02) | 0.48 | (1.16) |
| **GINI** | | | -0.18** | (0.04) | -0.03 | (0.08) | -0.19** | (0.04) | -0.13** | (0.03) |
| **HC_GINI** | -0.03* | (0.02) | -0.01 | (0.03) | -0.01 | (0.04) | -0.02 | (0.04) | -0.03 | (0.03) |
| **lnTFR** | -1.88 | (2.58) | 0.06 | (2.69) | 0.33 | (3.19) | -1.68 | (2.44) | -0.33 | (1.93) |
| **Wtd_DTFR** | 4.45 | (32.46) | 32.62 | (38.12) | -38.23 | (55.62) | 60.87** | (29.96) | 17.37 | (29.86) |
| **HC_Acc_rate** | 0.00 | (0.03) | 0.00 | (0.04) | -0.13* | (0.08) | 0.02 | (0.03) | -0.03 | (0.04) |
| **HCHC_ini** | | | | | | | | | | |
| **HC** | | | -0.28 | (0.38) | 14.55** | (5.24) | -0.31 | (0.39) | 3.91** | (1.57) |
| **HC_ini** | | | | | -13.59** | (4.77) | | | -3.99** | (1.38) |
| **N** | 69 | | 60 | | 60 | | 60 | | 60 | |
| **Weak ID test** | 0.35 | | 0.32 | | 0.20 | | 0.36 | | 0.23 | |
| **J-test** | 18.65 | [0.00] | 8.79 | [0.03] | 3.30 | [0.19] | 8.24 | [0.08] | 9.25 | [0.03] |

Notes for Tables 23 (a), (b) and (c): The dependent variable is the growth rate of real per capita GDP. Estimation by GMM. Standard errors are clustered by country. Heteroskedasticity-consistent standard errors are reported in parentheses The instrument set used varies as follows; all specifications include the 12 instruments used earlier but also: HC accumulation rate initial for column (1), initial HC accumulation rate for column (2), initial HC stock, initial HC accumulation rate for column (3) , initial HC accumulation rate, initial HC stock, Natural disasters for column (4) and initial HC accumulation rate , Natural disasters for column (5).

*Significant at the 10 % level. ** Significant at the 5 % level.

Figure 1



## Documentation for the Data

**De La Croix & Doepke**
Bangladesh, Benin, Bolivia, Botswana, Brazil, Burkina Faso, Burundi, Cameroon, Central African Rep., Colombia, Costa Rica, Czechoslovakia, Denmark, Dominican Rep., Ecuador, Egypt, El Salvador, Finland, France, Ghana, Guatemala, Guyana, Haiti, Indonesia, Italy, Ivory Coast, Jamaica, Jordan, Kenya, Korea Rep., Lesotho, Liberia, Madagascar, Malawi, Malaysia, Mali, Mexico, Morocco, Namibia, Niger, Nigeria, Norway, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Romania, Rwanda, Senegal, Spain, Sri Lanka, Sudan, Syria, Thailand, Togo, Trinidad & Tobago, Tunisia, Turkey, U.K., U.S.A., Uganda, Venezuela, Yemen, Yugoslavia, Zambia, Zimbabwe.

**Marianthi Anastasatou**
My final sample consists of 57 countries instead of 68 since there are 11 countries that had to be excluded from the initial list due to data availability. They are Burkina Faso, Czechoslovakia, Lesotho, Liberia, Mali, Niger, Romania, Sudan, Togo, Yemen and Yugoslavia. This leaves the first sample with 32 observations instead of 40 and the second sample with 36 instead of 43.

## GROWTH

I recalculate all the growth rates for both samples using "Real GDP per capita (Constant Prices: Chain series)" from PWT 6.1. It is quite possible that DDC & D has used an earlier version of PWT namely Version 5.6 or 6.0. In PWT 6.1, the base year is 1996; so all the constant price series will be substantially higher than PWT 5.6.
National Accounts: Many of the underlying national accounts of countries will have been revised since 1995 and these changes have been incorporated in the new version. PWT6.0 was mainly based on the World Development Indicators (WDI) 2000 disk, while PWT6.1 uses the WDI 2002 national accounts for non-OECD countries, and the OECD 2002 national accounts for 30 OECD countries. Data for years not in the WDI or OECD disks are obtained from previous national accounts files used in PWT5.6 and earlier versions.

1. Czechoslovakia: No data are given by PWT 6.1. The availability of them starts at 1990, which of course refer to Czech Republic.

2. Haiti: Growth rate for the first sample is restricted to the use of 1967-1976 values due to data availability.

3. Liberia: No data are available for both samples.

4. Poland: Growth rate for the first sample is calculated by using "Real GDP per capita (Constant Prices: Laspeyrs)" for 1970-1976 and for the second period I use "Real GDP per capita (Constant Prices: Chain series)" but for 1979-1992 due to data availability.

5. Sudan: No data are available for both samples.

6. Tunisia: Growth rate for the first sample is restricted to the use of 1961-1976 values due to data availability.

7. Yemen: Data are available only for 1990-1992 and hence the country has to be excluded.

8. Yugoslavia: No data are available for both samples.

*Data Source: Penn World Table (PWT) Version 6.1*

**INITIAL GDP**

I use "Real GDP per capita (Constant Prices: Chain series)" for 1960 and 1976 respectively.

1. Czechoslovakia: No data are given by PWT 6.1. Availability of them starts at 1990 that of course refer to Czech Republic.

2. Haiti: The initial GDP for the first period refers to 1967 due to data availability.

3. Liberia: No data are available for both samples.

4. Poland: First period's initial GDP represents "Real GDP per capita (Constant Prices: Laspeyrs)" for 1970 and second's period initial GDP represents "Real GDP per capita (Constant Prices: Chain series)" for 1979.

5. Sudan: No data are available for both samples.

6. Tunisia: Relevant observation refers to 1961.

7. Yemen: Data are available only for 1990-1992 and hence the country has to be excluded.

8. Yugoslavia: No data are available for both samples.

*Data Source: Penn World Table (PWT) Version 6.1*

## INITIAL I/GDP

1. Czechoslovakia: No data are given by PWT 6.1 .Availability of them starts at 1990 which of course refer to Czech Republic.
2. Liberia: No data are available for both samples.
3. Poland: The relevant observation corresponds to 1970.
4. Sudan: No data are available for both samples.
5. Tunisia: Relevant observation refers to 1961.
6. Yemen: Data are available only for 1990-1992 and hence the country has to be excluded.
7. Yugoslavia: No data are available for both samples.

*Data Source: Penn World Table (PWT) Version 6.1*

## INITIAL G/GDP

1. Czechoslovakia: No data are given by PWT 6.1 .Availability of them starts at 1990 which of course refer to Czech Republic.
2. Liberia: No data are available for both samples.
3. Poland: The relevant observation corresponds to 1970.
4. Sudan: No data are available for both samples.
5. Tunisia: Relevant observation refers to 1961.
6. Yemen: Data are available only for 1990-1992 and hence the country has to be excluded.
7. Yugoslavia: No data are available for both samples.

*Data Source: Penn World Table (PWT) Version 6.1*

## I/GDP

I recalculate the average rates for both samples. I use "Investment Share of CGDP" (CGDP stands for Real GDP per capita).

1. Czechoslovakia: No data are given by PWT 6.1 .Availability of them starts at 1990 which of course refer to Czech Republic.
2. Haiti: The average rate is calculated without 1966 due to data availability.
3. Liberia: No data are available for both samples.
4. Poland: The average rate for the first period is calculated for the years 1970-1976 whereas 1978 is excluded from second period's average due to data availability.
5. Sudan: No data are available for both samples.
6. Tunisia: The average rate for the first period is calculated for the years 1961-1976 due to data availability.
7. Yemen: Data are available only for 1990-1992 and hence the country has to be excluded.
8. Yugoslavia: No data are available for both samples.

*Data Source: Penn World Table (PWT) Version 6.1*

## G/GDP

I recalculate the average rates for both samples. I use "Government Share of CGDP" (CGDP stands for Real GDP per capita)

1. Czechoslovakia: No data are given by PWT 6.1 .Availability of them starts at 1990 which of course refer to Czech Republic.
2. Haiti: The average rate is calculated without 1966 due to data availability.
3. Liberia: No data are available for both samples.
4. Poland: The average rate for the first period is calculated for the years 1970-1976 whereas 1978 is excluded from second period's average due to data availability.
5. Sudan: No data are available for both samples.

6. Tunisia: The average rate for the first period is calculated for the years 1961-1976 due to data availability.

7. Yemen: Data are available only for 1990-1992 and hence the country has to be excluded.

8. Yugoslavia: No data are available for both samples.

*Data Source: Penn World Table (PWT) Version 6.1*

### AFRICA DUMMY

**Notes** I have checked the case that the "Africa Dummy" stands for a "Sub-Saharan Dummy", but I had rejected such a hypothesis.

(D=1 if country belongs to Africa)

**DLC & D**

Cameroon, Ghana, Kenya, Madagascar, Malawi, Namibia, Niger, Nigeria, Senegal, Zambia, Zimbabwe.

**MA**

Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Rep., Egypt, Ghana, Ivory Coast, Kenya, Liberia, Lesotho, Madagascar, Malawi, Mali, Morocco, Namibia, Niger, Nigeria, Rwanda, Senegal, Sudan, Togo, Tunisia, Uganda, Zambia, Zimbabwe.

### FERTILITY

**Note**: Initial Total Fertility refers to 1960 for the first period and 1975 for the second period.

Guyana's Initial Fertility for '60-'76: 6.88 according to De La Croix

: 6.14 according to Barro-Lee

*Data Source: Barro & Lee (1994)*

### LIFE EXPECTANCY

**Note**: Life Expectancy refers to 1960 for the first period and 1975 for the second period.

Ecuador's Initial Life Expectancy for '60-'76: 53.40 according to De La Croix

: 54.30 according to Barro-Lee

*Data Source: Barro & Lee (1994)*

## TROPICS DUMMY AND ACCESS DUMMY

**DLC & D**

*Data source: Sachs and Warner (1997) ACCESS and TROPICS variables.*

ACCESS: Physical access to international waters is measured by our land-locked variable. A country that borders the ocean (a "coastal economy") and that has a container port is given a value of 0, reflecting complete access to international shipping. A landlocked country without navigable access to the sea via rivers is given a value of 1.

TROPICS: Tropical climate is measured by a variable that takes the value 1 for a country in which the entire land area is subject to a tropical climate, and 0 for a country with no land area subject to a tropical climate. Countries in between these two extremes are assigned a fraction representing the approximate proportion of land area subject to a tropical climate.

**MA**

I use dummies (TROPICS=1 if country lies between the two Tropics, ACCESS=1 if country does not have access to the sea)

| | Sachs & Warner | | De La Croix & Doepke | | MA | |
|---|---|---|---|---|---|---|
| COUNTRY | TROPICS | ACCESS | TROPICS | ACCESS | TROPICS | ACCESS |
| BANGLADESH | 0.1 | 0 | 0.10 | 0 | 0 | 0 |
| BENIN | 1 | 0 | 0.00 | 0 | 1 | 0 |
| BOLIVIA | 1 | 1 | 1.00 | 1 | 1 | 1 |
| BOTSWANA | 0.5 | 1 | 0.00 | 0 | 1 | 1 |
| BRAZIL | 0.5 | 0 | 0.00 | 0 | 1 | 0 |
| BURKINA FASO | 1 | 1 | 1.00 | 1 | 1 | 1 |
| BURUNDI | 1 | 1 | 0.00 | 0 | 1 | 1 |
| CAMEROON | 1 | 0 | 1.00 | 0 | 1 | 0 |
| CENTRAL AFR.R. | 1 | 1 | 1.00 | 1 | 1 | 1 |
| COLOMBIA | 1 | 0 | 1.00 | 0 | 1 | 0 |
| COSTA RICA | 1 | 0 | 0.00 | 0 | 1 | 0 |
| CZECHOSLOVAKIA | | | 0.00 | 0 | 0 | 1 |
| DENMARK | 0 | 0 | 0.00 | 0 | 0 | 0 |
| DOMINICAN REP. | 1 | 0 | 1.00 | 0 | 1 | 0 |

| | Sachs & Warner | | De La Croix & Doepke | | MA | |
|---|---|---|---|---|---|---|
| ECUADOR | 1 | 0 | 0.00 | 0 | 1 | 0 |
| EGYPT | 1 | 0 | 1.00 | 0 | 0 | 0 |
| EL SALVADOR | 1 | 0 | 0.00 | 0 | 1 | 0 |
| FINLAND | 0 | 0 | 0.00 | 0 | 0 | 0 |
| FRANCE | 0 | 0 | 0.00 | 0 | 0 | 0 |
| GHANA | 1 | 0 | 1.00 | 0 | 1 | 0 |
| GUATEMALA | 1 | 0 | 0.00 | 0 | 1 | 0 |
| GUYANA | 1 | 0 | 0.00 | 0 | 1 | 0 |
| HAITI | 1 | 0 | 0.00 | 0 | 1 | 0 |
| INDONESIA | 1 | 0 | 1.00 | 0 | 1 | 0 |
| ITALY | 0 | 0 | 0.00 | 0 | 0 | 0 |
| IVORY COAST | 1 | 0 | 0.00 | 0 | 1 | 0 |
| JAMAICA | 1 | 0 | 0.00 | 0 | 1 | 0 |
| JORDAN | 0 | 1 | 0.00 | 1 | 0 | 0 |
| KENYA | 1 | 0 | 1.00 | 0 | 1 | 0 |
| KOREA, SOUTH | 0 | 0 | 0.00 | 0 | 0 | 0 |
| LESOTH | | | 0.00 | 0 | 0 | 1 |
| LIBERIA | | | 0.00 | 0 | 1 | 0 |
| MADAGASCAR | 0.9 | 0 | 0.90 | 0 | 1 | 0 |
| MALAWI | 1 | 1 | 1.00 | 1 | 1 | 1 |
| MALAYSIA | 1 | 0 | 0.00 | 0 | 1 | 0 |
| MALI | 1 | 1 | 0.00 | 0 | 1 | 1 |
| MEXICO | 0.5 | 0 | 0.00 | 0 | 1 | 0 |
| MOROCCO | 0 | 0 | 0.00 | 0 | 0 | 0 |
| NAMIBIA | | | 0.00 | 0 | 1 | 0 |
| NIGER | 1 | 1 | 1.00 | 1 | 1 | 1 |
| NIGERIA | 1 | 0 | 1.00 | 0 | 1 | 0 |
| NORWAY | 0 | 0 | 0.00 | 0 | 0 | 0 |
| PAKISTAN | 0 | 0 | 0.00 | 0 | 0 | 0 |
| PANAMA | | | 0.00 | 0 | 1 | 0 |
| PARAGUAY | 0.5 | 1 | 0.50 | 1 | 1 | 1 |
| PERU | 1 | 0 | 1.00 | 0 | 1 | 0 |
| PHILIPPINES | 1 | 0 | 1.00 | 0 | 1 | 0 |
| POLAND | | | 0.00 | 0 | 0 | 0 |
| ROMANIA | | | 0.00 | 0 | 0 | 0 |
| RWANDA | 1 | 1 | 1.00 | 1 | 1 | 1 |

| | Sachs & Warner | | De La Croix & Doepke | | MA | |
|---|---|---|---|---|---|---|
| SENEGAL | 1 | 0 | 1.00 | 0 | 1 | 0 |
| SPAIN | 0 | 0 | 0.00 | 0 | 0 | 0 |
| SRI LANKA | 1 | 0 | 0.00 | 0 | 1 | 0 |
| SUDAN | | | 0.00 | 0 | 1 | 0 |
| SYRIA | 0 | 0 | 0.00 | 0 | 0 | 0 |
| THAILAND | 1 | 0 | 0.00 | 0 | 1 | 0 |
| TOGO | 1 | 0 | 0.00 | 0 | 1 | 0 |
| TRINIDAD & TOBAGO | 1 | 0 | 0.00 | 0 | 1 | 0 |
| TUNISIA | 0 | 0 | 0.00 | 0 | 0 | 0 |
| TURKEY | 0 | 0 | 0.00 | 0 | 0 | 0 |
| U.K. | 0 | 0 | 0.00 | 0 | 0 | 0 |
| U.S.A. | 0 | 0 | 0.00 | 0 | 0 | 0 |
| UGANDA | 1 | 1 | 0.00 | 0 | 1 | 1 |
| VENEZUELA | 1 | 0 | 0.00 | 0 | 1 | 0 |
| YEMEN | | | 0.00 | 0 | 1 | 0 |
| YOGOSLAVIA | | | 0.00 | 0 | 0 | 0 |
| ZAMBIA | 1 | 1 | 1.00 | 1 | 1 | 1 |
| ZIMBABWE | 1 | 1 | 1.00 | 1 | 1 | 1 |

# GINI

| GINI 1960-1976 | | | | | | |
|---|---|---|---|---|---|---|
| | DLC & D | | | MA | | |
| | Quality | Year | Gini | Quality | Year | Gini |
| BANGLADESH | accept | 1963 | 37.31 | accept | 1963 | 37.31 |
| BENIN | | | 43.00 | | | 43 |
| BOLIVIA | | | | | | |
| BOTSWANA | | | | | | |
| BRAZIL | | | | | | |
| BURKINA FASO | | | | | | |
| BURUNDI | | | | | | |
| CAMEROON | accept | 1983 | 49.00 | | | |
| CENTRAL AFR.R. | | | | | | |
| COLOMBIA | nn | 1960 | 59.22 | nn | 1960 | 59.22 |
| COSTA RICA | accept | 1961 | 50.00 | accept | 1961 | 50 |
| CZECHOSLOVAKIA | accept | 1958 | 27.19 | accept | 1958 P | 27.19 |
| DENMARK | ps | 1963 | 39.00 | ps | 1963 | 39 |
| DOMINICAN REP. | nn | 1969 | 49.28 | nn | 1969 H | 49.28 |
| ECUADOR | nn | 1965 | 67.83 | nn | 1965 | 67.83 |
| EGYPT | | | | | | |
| EL SALVADOR | | | | | | |
| FINLAND | accept | 1966 | 31.80 | ps | 1962 H | 47 |
| FRANCE | accept | 1962 | 49.00 | accept | 1962 | 49 |
| GHANA | accept | 1988 | 35.90 | | | |
| GUATEMALA | | | | | | |
| GUYANA | accept | 1956 | 56.16 | accept | 1956 | 56.16 |
| HAITI | | | 52.00 | | | 52 |
| INDONESIA | | | | | | |
| ITALY | accept | 1974 | 41.00 | accept | 1974 | 41 |
| IVORY COAST | ps | 1959 | 45.56 | ps | 1959 P | 39.6 |
| JAMAICA | accept | 1958 | 54.31 | accept | 1958 | 54.31 |
| JORDAN | accept | 1980 | 40.80 | | | |
| KENYA | ps | 1976 | 68.00 | ps | 1961 | 48.8 |
| KOREA REP. | accept | 1961 | 32.00 | accept | 1961 | 32 |
| LESOTHO | accept | 1987 | 56.02 | | | |
| LIBERIA | | | | | | |

| | DLC & D | | | MA | | |
|---|---|---|---|---|---|---|
| | Quality | Year | Gini | Quality | Year | Gini |
| MADAGASCAR | | | | | | |
| MALAWI | | | | | | |
| MALAYSIA | accept | 1970 | 50.00 | cs | 1958 | 36 |
| MALI | | | | | | |
| MEXICO | accept | 1957 | 55.10 | accept | 1963 | 55.5 |
| MOROCCO | wg-ps | 1960-1965 | 50.00 | wg-ps | 1960-1965 | 50 |
| NAMIBIA | | | | | | |
| NIGER | | | | | | |
| NIGERIA | | | | | | |
| NORWAY | accept | 1962 | 37.52 | accept | 1962 | 37.52 |
| PAKISTAN | ps | 1963 | 34.70 | ps | 1963 | 38.65 |
| PANAMA | accept | 1970 | 57.00 | nn | 1962 | 36.09 |
| PARAGUAY | nn | 1983 | 45.10 | | | |
| PERU | accept | 1971 | 55.00 | nn | 1961 | 75.82 |
| PHILIPPINES | accept | 1961 | 49.71 | accept | 1961 | 49.71 |
| POLAND | wg | 1960 | 27.19 | ps | 1965 | 26 |
| ROMANIA | accept | 1989 | 23.38 | | | |
| RWANDA | | | | | | |
| SENEGAL | | | | ps | 1960 | 56.00 |
| SPAIN | accept | 1965 | 31.99 | accept | 1965 | 31.99 |
| SRI LANKA | | | | | | |
| SUDAN | | | | accept | 1968 | 38.72 |
| SYRIA | | | 49.46 | | | 49.46 |
| THAILAND | | | | | | |
| TOGO | | | | | | |
| TRINIDAD&TOBAGO | accept | 1958 | 46.02 | accept | 1958 | 46.02 |
| TUNISIA | | | | | | |
| TURKEY | | | | | | |
| U.K. | accept | 1961 | 25.30 | accept | 1961 | 25.3 |
| U.S.A. | accept | 1960 | 34.88 | accept | 1960 | 34.88 |
| UGANDA | | | | | | |
| VENEZUELA | nn | 1962 | 45.20 | ps | 1962 | 53.1 |
| YEMEN | | | | | | |
| YUGOSLAVIA | accept | 1963 | 31.18 | accept | 1963 | 31.18 |
| ZAMBIA | | | | | | |
| ZIMBABWE | | | | | | |

| GINI 1976-1992 | | | | | | |
|---|---|---|---|---|---|---|
| | DLC & D | | | MA | | |
| | Quality | Year | Gini | Quality | Year | Gini |
| BANGLADESH | accept | 1977 | 33.34 | accept | 1977 | 33.34 |
| BENIN | | | | | | |
| BOLIVIA | nn | 1986 | 51.57 | nn | 1986 | 51.57 |
| BOTSWANA | nn | 1975 | 52.00 | nn | 1975 | 52.00 |
| BRAZIL | accept | 1976 | 60.29 | accept | 1976 | 60.29 |
| BURKINA FASO | accept | 1995 | 39.00 | | | |
| BURUNDI | | | 42.00 | | | 42.00 |
| CAMEROON | accept | 1983 | 49.00 | accept | 1983 | 49.00 |
| CENTRAL AFR.R. | | | 43.00 | | | 43.00 |
| COLOMBIA | accept | 1978 | 54.50 | accept | 1978 | 54.50 |
| COSTA RICA | | | | | | |
| CZECHOSLOVAKIA | | | | | | |
| DENMARK | | | | | | |
| DOMINICAN REP. | accept | 1976 | 45.00 | accept | 1976 | 45.00 |
| ECUADOR | wg | 1970 | 68.26 | wg | 1987 | 44.53 |
| EGYPT | accept | 1975 | 38.00 | accept | 1975 | 38.00 |
| EL SALVADOR | accept | 1977 | 48.40 | accept | 1977 | 48.40 |
| FINLAND | | | | | | |
| FRANCE | | | | | | |
| GHANA | accept | 1988 | 35.90 | accept | 1988 | 35.90 |
| GUATEMALA | accept | 1979 | 49.72 | accept | 1979 | 49.72 |
| GUYANA | | | | | | |
| HAITI | | | | | | |
| INDONESIA | accept | 1976 | 34.60 | accept | 1976 | 34.60 |
| ITALY | | | | | | |
| IVORY COAST | | | | | | |
| JAMAICA | | | | | | |
| JORDAN | accept | 1980 | 40.80 | accept | 1980 | 40.80 |
| KENYA | tax | 1974 | 69.00 | ps | 1976 | 52.00 |
| KOREA REP. | | | | | | |
| LESOTHO | | | | | | |
| LIBERIA | ps | 1974 | 43.00 | ps | 1974 | 43.00 |
| MADAGASCAR | nn | 1980 | 48.90 | nn | 1980 | 48.90 |
| MALAWI | nn | 1977 | 51.80 | nn | 1977 | 51.80 |

| | DLC & D | | | MA | | |
|---|---|---|---|---|---|---|
| | Quality | Year | Gini | Quality | Year | Gini |
| MALAYSIA | | | | | | |
| MALI | accept | 1994 | 54.00 | | | |
| MEXICO | accept | 1975 | 57.90 | accept | 1977 | 50.00 |
| MOROCCO | nn | 1977 | 51.80 | nn | 1977 | 51.80 |
| NAMIBIA | | | 43.00 | | | 43.00 |
| NIGER | accept | 1992 | 36.10 | | | |
| NIGERIA | ps | 1975 | 35.50 | ps | 1975 | 35.50 |
| NORWAY | | | | | | |
| PAKISTAN | accept | 1979 | 32.32 | accept | 1979 | 32.32 |
| PANAMA | | | | | | |
| PARAGUAY | nn | 1983 | 45.10 | nn | 1983 | 45.10 |
| PERU | accept | 1981 | 49.33 | accept | 1981 | 49.33 |
| PHILIPPINES | accept | 1971 | 49.39 | cs | 1975 | 45.20 |
| POLAND | | | | | | |
| ROMANIA | | | | | | |
| RWANDA | accept | 1983 | 28.90 | accept | 1983 | 28.90 |
| SENEGAL | accept | 1991 | 54.12 | | | |
| SPAIN | | | | | | |
| SRI LANKA | accept | 1973 | 35.30 | accept | 1979 | 43.50 |
| SUDAN | accept | 1968 | 38.72 | | | |
| SYRIA | | | | | | |
| THAILAND | accept | 1975 | 41.74 | accept | 1975 | 41.74 |
| TOGO | ps | 1957 | 33.80 | | | |
| TRINIDAD&TOBAGO | accept | 1976 | 46.09 | accept | 1976 | 46.09 |
| TUNISIA | accept | 1975 | 44.00 | accept | 1975 | 44.00 |
| TURKEY | accept-cov | 1973-1978 | 51.00 | accept | 1973 | 51.00 |
| U.K. | | | | | | |
| U.S.A. | | | | | | |
| UGANDA | accept | 1989 | 33.00 | accept | 1989 | 33.00 |
| VENEZUELA | | | | | | |
| YEMEN | | | | | | |
| YUGOSLAVIA | | | | | | |
| ZAMBIA | accept | 1976 | 51.00 | accept | 1976 | 51.00 |
| ZIMBABWE | accept | 1990 | 56.83 | accept | 1990 | 56.83 |

**Notes:** There is a trade-off between the quality of the data available and precision (the Gini coefficient should belong to the initial year or as close as possible). The rule I follow is the use of the observation that comes from the first five years of the period in interest if it compensates by its quality. Lower quality observation is used if no data are available for that first quinquenniad. As for the recipient unit household equivalent is preferred to person equivalent.

Data Sources:

- *Deininger & Squire (1996).*
- For Benin, Burundi, Central Africa and Namibia data come from the *Economic Report on Africa 1999: The challenges of Poverty Reduction and Sustainability, UN (2000).* There is no reference to year.
- For Haiti and Syria I use the predicted values that De La Croix has used i.e. the predicted values of the available income Ginis on the land Ginis (*Jazairy et al. 1992*).

## DIFFERENTIAL FERTILITY

### Sample '60-'76

There is a correspondence problem concerning the year that the observations are supposed to describe and the year that they are actually belong to. The observations of 24 out of 40 countries belong to years outside the period in interest. So, 24 observations come from 1977-1982 and the rest 16 come from 1974-1976.

1. Sudan: An observation is available by United Nations, 1987 but is assigned to second sample period.

2. Senegal: Same as above.

*Source: United Nations, 1987 and Jones, 1982*

### Sample '76-'92

The representation is slightly better. The surveys used give data for 1985-1989 and 1990-1994 with 10 observations out of 43 coming from years later than 1992. In the cases that there are two observations from the Demographic and Health Surveys, I follow De La Croix and average the two resulting values.

1. Sudan: The observation comes from the data set used for the first sample. The observation comes from 1978 and although it belongs to the sample period, it shows inconsistency on the criteria used by the authors.

2. Senegal: They average two values but one observation is coming from the data set used for the first sample period. So, they are using 7 and 3.6 for f+, f- respectively (United Nations, 1995) and 7.3 and 4.5 (United Nations, 1987). Later values come from 1978 but again once again although it belongs to the sample period, it shows inconsistency on the criteria used by the authors. I correct this by using 7 and 3.6 for f+, f- respectively (United Nations (1995)) and 5.85 and 3.19 for f+, f- respectively (Mboup and Saha (1998)).

3. Trinidad & Tobago: They set f+ equal to 4.3 whereas according to the original source it is 2.3.

*Source: United Nations (1995) and Mboup and Saha ( 1998).*

## WEIGHTED DIFFERENTIAL FERTILITY

I approximate Wtd-DTFR as the coefficient from the weighted least squares regression of ln(TFR) on years of education, where observations are weighted by the percentage of women in the education category In the cases that there are two observations from the Demographic and Health Surveys. I average the two resulting values.

*Source: Kremer and Chen (2002)*

## HUMAN CAPITAL GINI

I follow Castello and Domenech (2002) and use the Gini coefficient that is based on the educational information for the population aged 15 and over, not the one of the population aged 25 and over, since the great part of my sample corresponds to developing countries where large portion of the labour force is younger than 25. (I use percentages).

*Data Source: http://iei.uv.es/~rdomenec/human/h_ineq.html*

### HUMAN CAPITAL ACCUMULATION RATE

1960-1976: Average of "Total gross enrolment ratio for secondary education"

1976-1992: Average of "Total gross enrolment ratio for secondary education"

(I use percentages).

*Data Source: Barro and Lee (1994)*

### INITIAL HUMAN CAPITAL ACCUMULATION RATE

"Total gross enrolment ratio for secondary education" for 1960 and 1975 respectively.

(I use percentages).

*Data Source: Barro and Lee (1994)*

### HUMAN CAPITAL

1960-1976: Average of "Average schooling years in the total population"

1976-1992: Average of "Average schooling years in the total population"

*Data Source: Barro and Lee (2001)*

### INITIAL HUMAN CAPITAL

"Average schooling years in the total population" for 1960 and 1975 respectively.

*Data Source: Barro and Lee (2001)*

### NATURAL DISASTERS

Logarithm of 1+ number of natural disaster events normalized by land area.

*Data Source: EMDAT, The OFDA/CRED International Disaster Database* for number of disasters, *CIA (2005)* for land area in million square kilometers

## 1960-1973

The countries used are the same as in the second set of regressions except from Poland which has to be excluded because PWT 6.1 gives data on I/GDP, G/GDP and "Real GDP per capita (Constant Prices: Chain series)" after 1970. The period now is shorter and I believe that the growth rates and averages will not be representative values of the period in interest.

### GROWTH

Haiti: Growth rate is calculated for 1967-1973.

Tunisia: Growth rate is restricted to the use of 1961-1976 values due to data availability.

*Data Source: Penn World Table (PWT) Version 6.1*

### I/GDP

Haiti: The average rate is calculated without 1966 due to data availability.

Tunisia: The average rate is calculated for the years 1961-1976 due to data availability.

*Data Source: Penn World Table (PWT) Version 6.1*

### G/GDP

Haiti: The average rate is calculated without 1966 due to data availability.

Tunisia: The average rate is calculated for the years 1961-1976 due to data availability.

*Data Source: Penn World Table (PWT) Version 6.1*

## 1976-1992

The comments made in Appendix I for the second period hold for this data set too.

## Countries

Bangladesh, Benin, Cameroon, Colombia, Costa Rica, Denmark, Dominican Rep., Ecuador, Finland, France, Ghana, Italy, Ivory Coast, Jamaica, Jordan, Kenya, Korea Rep., Lesotho, Malaysia, Mexico, Morocco, Norway, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Senegal, Spain, Syria, Trinidad & Tobago, U.K., U.S.A., Uganda, Venezuela.

## GINI

Data come from Deininger and Squire apart from Benin (Source: Economic Report on Africa 1999: The challenges of Poverty Reduction and Sustainability, UN (2000)) and Syria (I use the predicted values that De La Croix has used).

| COUNTRY | COMMENTS | YEAR | GINI |
|---|---|---|---|
| BANGLADESH | | | 33.34 |
| BENIN | UN | | 43 |
| CAMEROON | | | 49 |
| *COLOMBIA* | | | 54.5 |
| COSTA RICA | accept | 1977 | 50.00 |
| DENMARK | accept | 1976 | 31.00 |
| DOMINICAN REP. | | | 45 |
| ECUADOR | | | 44.53 |
| FINLAND | accept | 1977 | 30.45 |
| FRANCE | accept | 1975 | 43.00 |
| GHANA | | | 35.9 |
| ITALY | accept | 1976 | 35.00 |
| IVORY COAST | accept | 1985 | 41.21 |
| JAMAICA | accept | 1975 | 44.52 |
| JORDAN | | | 40.8 |
| KENYA | | | 52 |
| KOREA REP. | accept | 1976 | 39.10 |
| LESOTHO | accept | 1987 | 56.02 |
| MALAYSIA | accept | 1976 | 53.00 |
| MEXICO | | | 50 |
| MOROCCO | | | 51.8 |
| NORWAY | accept | 1976 | 37.30 |
| PAKISTAN | | | 32.32 |
| PANAMA | accept | 1979 | 48.76 |
| PARAGUAY | | | 45.1 |
| PERU | | | 49.33 |
| PHILIPPINES | | | 45.2 |
| POLAND | accept | 1976 | 25.81 |
| SENEGAL | ps | 1970 | 49.00 |
| SPAIN | accept | 1973 | 37.11 |
| SYRIA | Jazairy | 1979 | 49.46 |
| TRINIDAD&TOBAGO | | 46.09 | |
| U.K. | accept | 1976 | 23.20 |
| U.S.A. | accept | 1976 | 34.42 |
| VENEZUELA | accept | 1976 | 43.63 |

# Chapter 5

# Problems with Instrumental Variables estimation when an endogenous variable is instrumented by its squared value

[1]

## 5.1 Introduction

In Chapter 4 we saw that Doepke and De La Croix (2003) used as instruments the squared value of some of the endogenous variables. Such a specification might capture any possible non-linear effects between the RHS variables and the independent variable and thus improve the fit of the regression. However, the properties of such instruments as well as the implications for the Instrumental Variables (IV) estimator

[1]This paper is joint work with Dr Edmund Cannon.

have not been investigated. In this paper we show that whether the squared value of an endogenous RHS variable is a weak instrument and whether the IV estimator is biased depend on the distribution of the errors of the first and second stage regression in the 2SLS process of estimating IV when the sample is large. Then, we investigate the sensitivity of the bias of the IV estimator to various Monte Carlo data generating processes. Finally, we suggest two measures of testing the size of the bias of the IV estimator specific to the case when an endogenous variable is instrumented by its squared value.

The paper proceeds as follows. Section 2 sets the theoretical background and presents the conditions which need to be investigated. The implications of using the square of a RHS variables as instrument in large samples are explained in Section 3. Section 4 investigates the bias of the IV estimator in small samples. Section 5 concludes.

## 5.2 Potential problems from using $x^2$ as an instrument for $x$

Consider the relationship:

$$Y_i = \alpha + \beta X_i + u_i$$

where $E[u_i] = 0$ and $E[X_i u_i] \neq 0$. De-meaning the data (equivalent to including a constant in every regression) means this can be rewritten as:

$$y_i = \beta x_i + u_i \tag{5.1}$$

where $y_i = Y_i - \overline{Y}$, $x_i = X_i - \overline{X}$ and $E[u_i] = 0$, $E[x_i u_i] \neq 0$.

Consider using $x^2$ as an instrument for $x$. The IV estimator is then:

$$\widehat{\beta}_{IV} \equiv \frac{\sum x_i^2 y_i}{\sum x_i^2 x_i} = \frac{\sum x_i^2 (\beta x_i + u_i)}{\sum x_i^3} = \beta + \frac{\sum x_i^2 u_i}{\sum x_i^3}$$

and thus the bias is:

$$bias = \frac{\sum x_i^2 u_i}{\sum x_i^3} \tag{5.2}$$

Everything then depends upon the ratio of the two moments on the RHS of (5.2). If the sample is small then a valid instrument implies $\sum x_i^2 u_i = 0$. However, if $\sum x_i^3$ is small then $x^2$ is a weak instrument for $x$ and the IV estimator of $\beta$ might be biased. Similarly, If the sample is large then by construction $E\left[x_i^2 u_i\right] = 0$ and if $E\left[x_i^3\right] = 0$ then $x^2$ is a weak instrument for $x$ and the IV estimator of $\beta$ might be inconsistent.

In what follows, we investigate the conditions under which $x^2$ is a weak instrument for $x$ and $\widehat{\beta}_{IV}$ is biased for large and small samples respectively.

## 5.3 Results for large samples

### 5.3.1 $x_i$ and $u_i$ are jointly normally distributed

In the specific scenario where $x_i$ and $u_i$ are jointly Normally distributed, both the numerator and denominator of the expression (5.2) are zero in expectation (due to the symmetry of the Normal distribution). So, since the correlation between the endogenous variable and the instrument is zero, $x_i^2$ is a weak instrument for $x_i$.

Moreover, the asymptotic bias of the IV estimator is the same as the asymptotic bias of the OLS estimator. This is not immediately obvious, but it can be shown by going through the algebra. We assume that:

$$\begin{pmatrix} x_i \\ u_i \end{pmatrix} \sim \left( \begin{pmatrix} \mu_x \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_x^2 & \sigma_x \sigma_u \rho \\ \sigma_x \sigma_u \rho & \sigma_u^2 \end{pmatrix} \right)$$

The OLS estimator is:

$$\widehat{\beta}_{OLS} \equiv \frac{\sum y_i x_i}{\sum x_i^2}$$

and thus

$$
\begin{aligned}
plim\widehat{\beta}_{OLS} &= \frac{E\left[\left(\beta\left(x_i-\mu_x\right)+u_i\right)\left(x_i-\mu_x\right)\right]}{var\left(x_i\right)} \\
&= \beta+\frac{\sigma_u\rho}{\sigma_x}
\end{aligned}
$$

We calculate the IV estimator in two stages. We first fit:

$$x_i = a + \gamma x_i^2 + \varepsilon_i$$

and find that:

$$\widehat{\gamma} \equiv \frac{\sum x_i x_i^2}{\sum x_i^2}$$

and thus

$$
\begin{aligned}
plim\widehat{\gamma} &= \frac{E\left[\left(x_i-\mu_x\right)\left(x_i^2-\left(\sigma_x^2+\mu_x^2\right)\right)\right]}{E\left[x_i^2-\left(\sigma_x^2+\mu_x\right)\right]^2} \\
&= \frac{\mu_x}{2\mu_x^2+\sigma_x^2}
\end{aligned}
$$

since the raw moments for the Normal distribution are $E\left[x_i^2\right] = \sigma_x^2 + \mu_x^2$, $E\left[x_i^3\right] = 3\sigma_x^2\mu_x + \mu_x^3$ and $E\left[x_i^4\right] = \mu_x^4 + 6\mu_x^2\sigma_x^2 + 3\sigma_x^4$. Then, we regress $y_i$ on the estimated values of $x_i$ from the first stage i.e. we estimate:

$$y_i = \beta\widehat{x}_i + u_i$$

Thus, the IV estimator is:

$$\widehat{\beta}_{IV} \equiv \frac{\sum y_i\widehat{x}_i}{\sum \widehat{x_i^2}}$$

and

$$\begin{aligned}
plim\widehat{\beta}_{IV} &= \frac{E\left[\left(\beta\left(x_i-\mu_x\right)+u_i\right)\left(\frac{\mu_x}{2\mu_x^2+\sigma_x^2}x_i^2-\mu_x\right)\right]}{var\left(\frac{\mu_x}{2\mu_x^2+\sigma_x^2}x_i^2\right)} \\
&= \frac{\left(\beta\mu_x 2\mu_x\sigma_x^2+2\mu_x^2\sigma_x\sigma_u\rho\right)\left(2\mu_x^2+\sigma_x^2\right)^2}{\left(2\mu_x^2+\sigma_x^2\right)\mu_x^2\left(4\mu_x^2\sigma_x^2+2\sigma_x^4\right)} \\
&= \beta+\frac{\sigma_u\rho}{\sigma_x} \\
&= \widehat{\beta}_{OLS}
\end{aligned}$$

since $E\left[\widehat{x}_i\right]=\mu_x$ and $E\left[x_i^2u_i\right]=2\mu_x\sigma_x\sigma_u\rho$.

Summarizing, we find that when the sample is large and $x_i$ and $u_i$ are jointly Normally distributed, $x_i^2$ is a weak instrument for $x_i$, which follows from the obvious fact that the Normal distribution is not skew, and the IV estimator is biased.

### 5.3.2 More general cases

We now turn to investigating more general cases. When there are considerations about the endogeneity of $x_i$, it is $E\left[x_iu_i\right]\neq 0$. The non-zero correlation between the endogenous variable and the error can be proxied by a linear function:

$$x_i=\lambda u_i+\nu_i$$

For the purpose of this taxonomy we only consider situations where $u_i$ and $\nu_i$ are independent. To investigate the asymptotic bias of $\widehat{\beta}_{IV}$ as well as check whether $x^2$ is a good instrument for $x$, we need to calculate the expectations of the following two expressions:

$$\begin{aligned}
x_i^2u_i &= \lambda^2u_i^3+\nu_i^2u_i+2\lambda u_i^2\nu_i \\
x_i^3 &= \lambda^3u_i^3+3\lambda^2u_i^2\nu_i+3\lambda u_i\nu_i^2+\nu_i^3
\end{aligned}$$

It is obvious that everything now hinges on whether the distributions of $u_i$ and

$\nu_i$ are skew. The possible cases are outlined in Table 1.

| | | $u$ | |
|---|---|---|---|
| | | Not skew | Skew |
| $\nu$ | Not skew | $E\left[x_i^2 u_i\right] = 0$<br>$E\left[x_i^3\right] = 0$<br>$\widehat{\beta}_{IV}$ biased<br>weak instrument<br>$x_i$ not skew | $E\left[x_i^2 u_i\right] = \lambda^2 skew(u) > 0$<br>$E\left[x_i^3\right] = \lambda^3 skew(u) > 0$<br>$\widehat{\beta}_{IV}$ biased<br>non-weak instrument<br>$x_i$ skew |
| | Skew | $E\left[x_i^2 u_i\right] = 0$<br>$E\left[x_i^3\right] = skew(v) \neq 0$<br>$\widehat{\beta}_{IV}$ unbiased<br>non-weak instrument<br>$x_i$ skew | In general<br>$E\left[x_i^2 u_i\right] = \lambda^2 skew(u)$<br>$E\left[x_i^3\right] = \lambda^3 skew(u) + skew(v)$<br>$\widehat{\beta}_{IV}$ biased<br>non-weak instrument<br>$x_i$ skew<br><br>$Iff\ \lambda^3 skew(u) + skew(v) = 0$<br>$E\left[x_i^2 u_i\right] = \lambda^2 skew(u)$<br>$E\left[x_i^3\right] = 0$<br>$\widehat{\beta}_{IV}$ biased<br>weak instrument<br>$x_i$ not skew |

*Table 1*

If the distribution of $x_i$ is not skew (which we can observe from the data) then $x_i^2$ will be a weak instrument; this follows automatically from the fact that $x_i^2$ is a symmetric function of $x_i$ i.e. $E\left(x_i^3\right) = 0$. This result is regardless of the skewness of the residuals (which, in principle, we could attempt to infer from the estimated residuals), since we would be unable to test whether we were in the top left hand side box or the bottom right hand side box with the condition placed upon the skewness of $u_i$ and $\nu_i$.

If the distribution of $x_i$ is skew (which we can observe from the data), then $x_i^2$ will not be a weak instrument for $x_i$ since $E\left(x_i^3\right) \neq 0$. In other words, there will be a relationship between $x_i$ and $x_i^2$, which will be picked up in the F-statistic of the first stage regression in the 2SLS process of estimating IV. However, the IV estimate of $\beta$ will still be asymptotically biased unless $u_i$ is known to be symmetric and $\nu_i$ known to be asymmetric. A possible test for this, probably with reasonable size properties, would be to see whether the estimated residuals were not skew. If it were possible to reject skewness then it would be impossible to reject the null hypothesis that we were in the bottom left hand side box of the table, given that the distribution of $x_i$ is skew. However, the power of test would be deficient since, given the biased estimates of $\beta$, we might fail to reject the null (non skewness of $\widehat{u_i}$) even if we were in either of the RH boxes of the table, which constitutes the alternative.

Summarizing, we find that when the sample is large and $x_i$ and $u_i$ are jointly Normally distributed, $x_i^2$ is a weak instrument for $x_i$, which follows from the obvious fact that the Normal distribution is not skew, and the IV estimator is biased. However, in more general cases, $x_i^2$ is a good instrument for $x_i$ and the IV estimator is asymptotically unbiased only when the error from the first stage regression in the 2SLS process of estimating IV is skew and the error from the second stage is not skew.

## 5.4 Results for small samples

In the case of a small sample we check the effect of using $x_i^2$ as an instrument of $x_i$ by the use of simulations. We define $u_i$ to be normally distributed (not skewed) and $\nu_i$ to be distributed according to the $\chi^2_\kappa$ distribution where $\kappa$ is the degrees of freedom. The estimation model is:

$$y_i = \beta_0 + \beta_1 x_i + u_i$$

where

$$x_i = \alpha + \lambda u_i + \nu_i$$

We generate the errors using a Monte Carlo repeated random sampling. Under the null $\beta_0 = 0$ and $\beta_1 = 1$. Thus, the data generating process for $y_i$ is:

| number of replications | $n$ | all replications | only replications with $F > 10$ | |
|---|---|---|---|---|
| | | $bias(\widehat{\beta}_{IV})$ | $bias(\widehat{\beta}_{IV})$ | % of replications |
| 10,000 | 10 | 0.239 | 0.216 | 95.35 |
| | 20 | 0.153 | 0.153 | 99.73 |
| | 50 | 0.115 | 0.115 | 100 |
| | 100 | 0.1 | 0.1 | 100 |
| 20,000 | 10 | 0.231 | 0.217 | 95.515 |
| | 20 | 0.155 | 0.154 | 99.73 |
| | 50 | 0.115 | 0.115 | 100 |
| | 100 | 0.1 | 0.1 | 100 |
| 50,000 | 10 | 0.233 | 0.219 | 95.66 |
| | 20 | 0.158 | 0.157 | 99.71 |
| | 50 | 0.114 | 0.114 | 100 |
| | 100 | 0.099 | 0.099 | 100 |
| 100,000 | 10 | 0.236 | 0.219 | 95.68 |
| | 20 | 0.159 | 0.159 | 99.7 |
| | 50 | 0.115 | 0.115 | 100 |
| | 100 | 0.099 | 0.099 | 100 |

*Table 2. Relative bias of the IV estimator (benchmark case)*

$$y_i = x_i + u_i$$

and the data generating process for $x_i$ is:

$$x_i = 0.5u_i + \nu_i$$

where $u_i \sim N(0,1)$ and $\nu_i \sim \chi_1^2(1,2)$ (i.e. the degrees of freedom are $\kappa = 1$ so the distribution is highly skewed). We call this scenario ($\lambda = 1/2$) the benchmark case.

An obvious method to check whether $x_i^2$ is a good instrument for $x_i$ is to use the F-statistic (or the squared value of the t-statistic) of the first stage regression in the 2SLS. More specifically, one could filter the above replications by the value of the F-statistic and keep those observations for which the instrument appears non-weak. Stock and Yogo (2005) provide the critical values to which the F-statistic should compare. Unfortunately, the critical values are calculated for a minimum of three excluded instruments and cannot be used in our case. Thus, we need to follow a rule-of-thumb which suggests that an instrument is weak if the F-statistic of the first stage regression is less than 10.[2]

In Table 2 we present the bias of the IV estimator for $n$ = 10, 20, 50 and 100 sample size and for 10,000, 20,000, 50,000 and 100,000 number of replications. We find that the bias decreases as the sample size increases. When we drop the replications for which $x_i^2$ is a weak instrument for $x_i$, i.e. those replications for which $F < 10$, we find that the bias decreases in small sample sizes only, whereas it has no impact in bigger samples. Finally, as expected, the number of replications has a very small impact on the bias of the IV estimator. So, Monte Carlo replication error appears significantly small that it can be safely ignored. Thus, for the rest of the analysis we report the results for 50,000 replications only.

How do the results change if $u_i$ is distributed according to a skew distribution other than the Normal? If $u_i$ is distributed according to the Uniform distribution then the bias of the IV estimator is smaller compared to the case where $u_i \sim N(0,1)$. However, $x_i^2$ is a good instrument for $x_i$ for all replications regardless of the sample size (see Table 3). If $u_i$ is distributed according to the Student's t-distribution, with 3 degrees of freedom, the asymptotic bias of the IV estimator is greater than both previous cases (see Table 4). Finally, the bias decreases as the sample size increases

[2]Notice that there are no issues about normality as we are not using the F-test to identify significance but we only use the value of the F-statistic as a filter. Moreover, the value 10 is high enough (much higher than e.g. 2 that would be a typical value).

whether $u_i$ is distributed according to the Uniform or the student's t distribution.

| $n$ | all replications | only replications where $F > 10$ | |
|---|---|---|---|
| | $bias(\widehat{\beta}_{IV})$ | $bias(\widehat{\beta}_{IV})$ | % of the replications |
| 10 | 0.031 | 0.031 | 100 |
| 20 | 0.017 | 0.017 | 100 |
| 50 | 0.012 | 0.012 | 100 |
| 100 | 0.01 | 0.01 | 100 |

*Table 3. Relative bias of the IV estimator when $u_i$ is distributed according to the Uniform distribution*

| $n$ | all replications | only replications where $F > 10$ | |
|---|---|---|---|
| | $bias(\widehat{\beta}_{IV})$ | $bias(\widehat{\beta}_{IV})$ | % of the replications |
| 10 | 0.693 | 0.414 | 86.49 |
| 20 | 0.681 | 0.342 | 92.70 |
| 50 | 0.304 | 0.280 | 96.90 |
| 100 | 0.320 | 0.254 | 98.11 |

*Table 4. Relative bias of the IV estimator when $u_i$ is distributed according to $t_3$ distribution*

We next look on the role of $\lambda$ or, more generally, the role of the relative weight of $u_i$ and $\nu_i$. Thus, if the data generating process for $x_i$ is:

$$x_i = \lambda u_i + \gamma \nu_i$$

then for $u_i \sim N(0,1)$ and $\nu_i \sim \chi_1^2(1,2)$ we obtain:

$$var(x_i) = \lambda^2 + 2\gamma^2$$

For the benchmark case we have assumed that $\lambda = 1/2$ and $\gamma = 1$. Therefore, the variance of $x_i$ is greatly accounted for by the variance of $v_i$. If however, $\lambda = \gamma = 1$

i.e. equal weight of the errors in the data generating process of $x_i$, the bias of the IV estimator is higher than the benchmark case (see Table 5). If we allow for equal weights of $u_i$ and $\nu_i$ on the variance of $x_i$, then $\lambda = \sqrt{2}$ and $\gamma = 1$ and the bias of the IV estimator becomes higher, although is smaller than the case $\lambda = \gamma = 1$ (see Table 6). Finally, if the weight of $\nu_i$ for the variance of $x_i$ is very small e.g. $\lambda = 1$ but $\gamma = 0.1$, the bias of $\widehat{\beta}_{IV}$ appears bigger than all other scenarios. Moreover, $x_i^2$ is a weak instrument for $x_i$ for the majority of the replications (see Table 7). For the first two scenarios, the bias decreases with the sample size but there is a non-monotonic relation for the last case.

| $n$ | all replications | only replications where $F > 10$ | |
|---|---|---|---|
| | $bias(\widehat{\beta}_{IV})$ | $bias(\widehat{\beta}_{IV})$ | % of the replications |
| 10 | 0.321 | 0.278 | 79.45 |
| 20 | 0.242 | 0.233 | 93.31 |
| 50 | 0.190 | 0.190 | 99.84 |
| 100 | 0.171 | 0.171 | 100 |

*Table 5. Relative bias of the IV estimator for $\lambda = \gamma = 1$*

| $n$ | all replications | only replications where $F > 10$ | |
|---|---|---|---|
| | $bias(\widehat{\beta}_{IV})$ | $bias(\widehat{\beta}_{IV})$ | % of the replications |
| 10 | 0.304 | 0.291 | 66 |
| 20 | 0.275 | 0.254 | 81.59 |
| 50 | 0.214 | 0.22 | 97.83 |
| 100 | 0.203 | 0.203 | 99.96 |

*Table 6. Relative bias of the IV estimator for $\lambda = \sqrt{2}$ and $\gamma = 1$*

| $n$ | all replications | only replications where $F > 10$ | |
|---|---|---|---|
| | $bias(\widehat{\beta}_{IV})$ | $bias(\widehat{\beta}_{IV})$ | % of the replications |
| 10 | 1.071 | 0.978 | 26.41 |
| 20 | 2.012 | 0.976 | 22.19 |
| 50 | 1.268 | 0.972 | 22.40 |
| 100 | 1.184 | 0.968 | 26.07 |

*Table 7. Relative bias of the IV estimator for $\lambda = 1$ and $\gamma = 0.1$*

However, in order to use the alternative test which we suggested ein the case of the large sample and test the skewness of the estimated residuals, things are more complicated. The choice of the skewness statistic is not obvious. Various measures of sample skewness have been suggested. For very large samples the differences in definition is not important. However, in relatively smaller samples there might be differences in the size of the bias and the variance among the measures. We follow Joanes and Gill (1998) and use the following measure:

$$b_1 = \frac{m_3}{s^3} = \left(\frac{n-1}{n}\right)^{3/2} \frac{m_3}{m_2^{3/2}} = \frac{(n-1)^{3/2}}{n} \frac{\sum (x-\overline{x})^3}{\left(\sum (x-\overline{x})^2\right)^{3/2}}$$

They have shown that in Normally distributed small samples , $b_1$is unbiased and has the smallest mean-squared error among some popular measures whereas is biased but has the smallest mean square error in 100.000 samples of various sample sizes generated from $\chi^2$ distributions with 1, 10 and 50 degrees of freedom.

However, we have no prior as to how skewed $x_i$ should be. In other words, we don't know when the correlation between $x_i$ and $x_i^2$ is "high enough". Moreover, we cannot assume normality and thus trivial t-tests cannot be performed. Thus, we use the following approach. We calculate the skewness of $x_i$ for each replication, rank the skewness statistic and then calculate the bias of the IV estimator for various percentages of the replications which exhibit the highest skewness statistic. Finally, we compare the percentage of the samples dropped with the ones dropped when the

F-statistic test is used.

The results of this approach are given in Table 8. The bias of the IV estimator is greater when the filtering criterion for keeping the better performing replications is the skewness statistic compared to the F-statistic of the first stage regression in the 2SLS process, regardless of the sample size (for the sake of comparability we use the values of $\lambda$ and $\gamma$ of the benchmark case). Moreover, there is some evidence that the F-statistic might be a better test to check the desirability of $x_i^2$ as an instrument for $x_i$ for small samples. The bias for even the 20% best replications according to the F-statistic is higher than the bias of the 80% best replications according to the skewness statistic. This effect is weaker for bigger samples.

| | n | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 10 | | 20 | | 50 | | 100 | |
| | $F$ | $b_1$ | $F$ | $b_1$ | $F$ | $b_1$ | $F$ | $b_1$ |
| 80% | 0.178 | 0.223 | 0.130 | 0.148 | 0.104 | 0.108 | 0.098 | 0.095 |
| 70% | 0.160 | 0.223 | 0.121 | 0.145 | 0.102 | 0.105 | 0.098 | 0.093 |
| 60% | 0.145 | 0.224 | 0.113 | 0.140 | 0.100 | 0.103 | 0.098 | 0.091 |
| 50% | 0.132 | 0.225 | 0.107 | 0.138 | 0.098 | 0.100 | 0.097 | 0.089 |
| 40% | 0.120 | 0.224 | 0.100 | 0.133 | 0.096 | 0.097 | 0.096 | 0.086 |
| 30% | 0.107 | 0.230 | 0.192 | 0.128 | 0.093 | 0.092 | 0.094 | 0.083 |
| 20% | 0.092 | 0.246 | 0.085 | 0.123 | 0.088 | 0.087 | 0.093 | 0.079 |

*Table 8. Relative bias of the IV estimator*

## 5.5 Conclusion

This paper investigates the conditions under which the squared value of an endogenous variable is a non-weak instrument to use with Instrumental Variable estimation method and the implications for the IV estimator. The analysis shows that $x_i^2$ is a non-weak instrument for $x_i$ and the IV estimator is asymptotically unbiased only when the errors of the IV estimation are not skew and the errors of the first stage regression in the 2SLS process of estimating IV are skew. A possible test for that is to check the skewness of the estimated residuals. If it were possible to reject skewness then it would be impossible to reject the null hypothesis that the squared value of the endogenous variable is a non-weak instrument and the IV estimator is consistent. Simulations have shown that the bias decreases with the sample size and is highly sensitive to the error structure of the data generating process. We also find that the F-statistic of the first stage regression in the 2SLS process of estimating IV might be a better test than a test on the skewness of $x_i$ in assessing whether $x_i^2$ is a good instrument for $x_i$ especially if the sample is relatively small. In other words, our results caution about the use of the squared value of a right hand side variable as an instrument since the regression might suffer from the weak instrument problem and the IV estimator might be biased.

# Chapter 6

# Conclusion

This thesis examines four questions broadly involved with growth economics. Chapter 2 investigates the relation between credit markets and growth by modeling informational imperfections in a more rigorous manner compared to the existing literature. The technology used to obtain information about potential borrowers is allowed to be imperfect in the sense that lenders can identify the true type of the borrowers who declare themselves as high-risk with certainty but can draw an imperfect inference if borrowers declare themselves as low-risk. The importance of such an assumption is apparent in the light of the current crisis which pointed out that modern computerised screening techniques such as credit scoring are still far from perfect. The innovative prediction of the chapter is that although credit rationing can be used by all countries as a mechanism of separating borrowers, this does not hold for screening, contrary to earlier findings. More specifically, the analysis shows that in undeveloped countries rationing is the only equilibrium way of separating borrowers and the screening cost needs to decrease, or the difference in the rates of return between the home technology and an investment project to increase above a threshold, for the screening contract to become relevant. In developed economies, lenders can separate borrowers by denying credit to a fraction of them at low levels of capital accumulation whereas they start using a screening technology to obtain information about potential borrowers as capital accumulates. Such a transition from rationing to screening may imply a lower or higher dynamic path and steady state for the capital stock. The economic environment can change the equilibrium contract terms within each regime but can also change the equilibrium regime itself. Moreover, a screening regime does not always dominate a rationing regime in the sense of delivering higher dynamic capital paths and steady state level for capital, contrary to preexisting findings. Finally, the model verifies earlier findings about the "threshold effect" of the screening cost in the sence that a marginal change in policy may not be sufficient to push the economy to a higher growth path and steady state capital stock. Furthermore, it predicts that there are cases where the quality of screening should also be above a threshold level before it can affect an economy's growth path and the steady-state of capital.

These findings are important for policy makers since they will affect the priority which they attach to reforming financial sector policies. Consider, for example, a governmental policy to improve the informational infrastucture of the credit market by affecting the cost which screening entails or by setting specific monitoring standards. Such a policy would tend to cause an upward shif in the capital accumulation path and thus result to a higher steady state capital stock. However, our model shows that there are exceptions to this rule. In other words, the most important policy implication of this chapter is that it cautions not to folow the "one-fits-all" policy rule which past reasearch suggests. Measures that have been suggested to shift the capital accumulation path upwards and thus result to a higher steady state capital stock might be ineffective or even have a negative effect depending on the specifics of an economy.

An interesting extension of this work would be to endogenise the screening cost. This can be done by a two stage game solved by backward induction where the lenders choose to use the quality of screening which maximizes their expected payoff, given the contract terms which maximize the expected payoff of the borrowers. Another direction would be to allow the screening cost to depend on the quality of screening and allow learning to have a beneficial effect on the quality of the screening or its cost or allow for imperfections in the screening process of both risk-types of borrowers.

The third chapter suggests that financial development lead to lower markups in the Eurozone and US over the period 1981-2004. The empirical evidence advanced in this thesis suggests that financial depth has a greater effect on competition in sectors where firms are unusually dependent on external finance. This relation appears to be stronger over the period 1995-2004, perhaps due to the increased implementation of the EU Directives about the financial services industry and the adoption of the Euro. However, these results are not robust to the use of different measures for financial development or external dependence. Furthermore, there is strong evidence that the trade openness of countries is linked with higher competition and thus lower markups. This finding appears to be stronger for industries traditionally defined as tradable. Controlling simultaneously for trade openness and financial development shows that trade openness has greater explanatory power for the extent of competition compared to financial depth.

These findings are of obvious interest to competition authorities who would like to know whether specific policies are conducive to competition. The findings of this study suggest that both financial development and trade openness have pro-competitive effects with the later being more effective. Moreover, policy makers should be aware that the relation might be more sensitive for particular industries. Thus, measures enhancing the financial development or opening the country to trade might increase the competition in different industries disproportionately. This might also raise welfare considerations if the people who get affected belong to sensitive groups of the economy.

What remains an open question is whether openness has explanatory power for the extent of competition because it captures cross-country variation, in the sense that more open countries have lower markups overall, or is it due to cross-time effects i.e. more openening a country over time leads to smaller markups. The existence of a natural clustering which lead to openness having relatively higher significance for particular industries should also be investigated. Answering these questions would be natural extension of the present work.

The empirical relationship between income inequality and growth is the focal point of Chapter 3. The empirical findings of De La Croix and Doepke (2003) are challenged. They argue that the fertility-differential effect accounts for most of the empirical relationship between these two variables. Unfortunately, the empirical evidence advanced here does not support that claim. The replication of this result has not been possible. On the contrary, the evidence suggests that differential fertility is not linked to growth. Using either a better measure of differential fertility than the one used by DLCD or a more general specification leads to conclusion that the significance of differential fertility is open to considerable doubt. The evidence on the explanatory power which human capital inequality has on growth is not so strong though. It is quite probable that there is a different channel other than inequality in education and the differential fertility effect that links inequality to growth. Further research is needed to reach a sound conclusion for the cross section case since although differential fertility and inequality seems to have no explanatory variable for growth, the samples used may be too small to give reliable results. Finally, finding instruments that are exogenous and also have high correlation with the instrumented variables is a challenge for future work.

Chapter 5 addresses one of the points raised in the previous chapter about the reliability of the instrument set used. More specifically, the conditions under which the squared value of an endogenous variable is a non-weak instrument to use with Instrumental Variable estimation method and the implications for the IV estimator are investigated. The findings caution about the use of the squared value of a right hand side variable as an instrument since the regression might suffer from the weak instrument problem and the IV estimator might be biased. More specifically, the analysis shows that $x_i^2$ is a non-weak instrument for $x_i$ and the IV estimator is asymptotically unbiased only when the errors of the IV estimation are not skew and the errors of the first stage regression in the 2SLS process of estimating IV are skew. It also suggests testing for that by checking the skewness of the estimated residuals. If it were possible to reject skewness then it would be impossible to reject the null hypothesis that the squared value of the endogenous variable is a non-weak instrument and the IV estimator is asymptotically unbiased. The Monte Carlo repeated random sampling suggests a negative relation between the size of the bias and the sample size and high sensitivity to the error structure of the data generating process. The F-statistic of the first stage regression in the 2SLS process of estimating IV might be a more reliable test in assessing whether $x_i^2$ is a good instrument for $x_i$ compared to testing the the skewness of $x_i$, especially if the sample is relatively small.

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